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THE UNIVERSITY OF ALBERTA

A COMPARATIVE LIMNOLOGICAL STUDY OF LAC LA BICHE
AND BEAVER LAKE, ALBERTA

by



MORLEY EDWARD PINSENT

A THESIS

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FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "A Comparative Limnological Study of Lac La Biche and Beaver Lake, Alberta", submitted by Morley Edward Pinsent in partial fulfilment of the requirements for the degree of Master of Science.



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ABSTRACT

Lac La Biche and Beaver Lake, two lakes in North-eastern Alberta in different drainages but separated by a small expanse of land (3 1/4 km) were investigated. This separation made it possible to study the biota of lakes in close proximity but in separate drainages and to study the result of recolonization during the post-glacial period.

Collection of biota from the limnetic, benthic and littoral regions of the lakes was carried out in order to identify the inhabitants of the lakes as completely as possible. Differences in the floral and invertebrate components of the lakes were due to factors other than the lakes being in separate drainages, such as lack of a specific type of habitat. Differences in the piscine fauna of the two lakes were attributable to reasons other than the lakes being in separate drainages, since all of the fishes found were known to inhabit both drainages.

The major differences between Lac La Biche and Beaver Lake were those of dominant zooplankters and phytoplankters. The more active rate of primary production in Lac La Biche is thought to be the reason for a more abundant bottom fauna there. This more active rate of primary production and shorter turnover time of phytoplankton as well as the dominance of a small zooplankter may be the result of a large population of a planktonivorous species of fish, the tullibee, Leucichthys sp., in Lac La Biche which does not occur in Beaver Lake.

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I INTRODUCTION

Interest in the Beaver Drainage in Alberta and its relationship to Lac La Biche and the La Biche River was first shown by David Thompson in October of 1798 and Peter Fidler in 1799. To these men the Beaver Drainage provided a convenient, if arduous, connection to the Athabaska and, at that time, extreme Northwest via Lac La Biche (McGregor, 1963). The height of land separating the two drainages is low and easily overcome thus making comparative limnological work on Beaver Lake and Lac La Biche appealing for much the same reasons that the area was of interest to the early fur trading companies.

Unfortunately biological interest in the area has never reached the same height of enthusiasm as did the search for furs, and there has been no major biological investigation of these formerly important navigational waterways. Miller (1950) did some work in his attempts to control the fish tapeworm, Triaenophorus crassus Forel, on Square Lake, which is close to Lac La Biche. There is a letter in the files of the Fish and Wildlife Division office in Lac La Biche dated March 15, 1957 which suggests that Miller did a short analysis of the dissolved oxygen content of the waters of Lac La Biche at about that time. They indicate a winter stagnation with less than 1 ppm below 12 meters. Although the letter does not indicate when these samples were taken, from the date one might assume they were taken in late winter. Paetz (1953) undertook an analysis of the tullibee, Leucichthys sp., populations in

Lac La Biche following some erratic fluctuations of these important commercial fishes.

The present study was initiated in an attempt to elucidate some of the limnological differences and similarities existing between Beaver Lake and Lac La Biche, which represent adjacent headwaters of two distinct river systems which are the Athabaska and Churchill drainages. It is also hoped that this venture into a region previously untouched by limnological study will provide a foundation on which to base further hydrobiological investigations in this interesting region of Alberta.

II DESCRIPTION OF STUDY AREA

1. Region of the Lakes

Lac La Biche and Beaver Lake are situated in a transition zone between the heavily wooded parkland to the south and the boreal forest to the north. They lie about 218 kilometers (136 miles) northeast of Edmonton, Lac La Biche being $54^{\circ}50'$ North Latitude, $111^{\circ}50'$ West Longitude and Beaver Lake is $54^{\circ}45'$ North Latitude, $111^{\circ}50'$ West Longitude. The area consists of numerous lakes interspersed among moss bog with occasional outcrops of grey wooded soil. Lindsey, Pawluk and Odynsky (1962) describe the soils of the area as Dark Grey Wooded, Grey Wooded, and occasional glacial till, for the most part on a clay loam base. This soil survey regards the area as doubtful arable land or pasture and woodland. The topography of the area is extremely variable. In general it is gently rolling, but with many knolls with short steep sided slopes. Bayrock (in Lindsay, Pawluk and Odynsky) refers to the bedrock of the area as composed of slightly consolidated to unconsolidated bentonitic shales and sandstones of Late Cretaceous age. He classifies the glacial deposits as intermediate to hummocky dead ice moraine. Wynnyk et al. (1963) report the area immediately north of Lac La Biche to be sandy till with occasional glacial outwash and overlain to a large extent by sphagnum bog, which is so much a characteristic of the area. Northcote and Larkin (1963) place the region in the Cretaceous and Cenozoic Sedimentary geological region and in the subarctic climatic region.

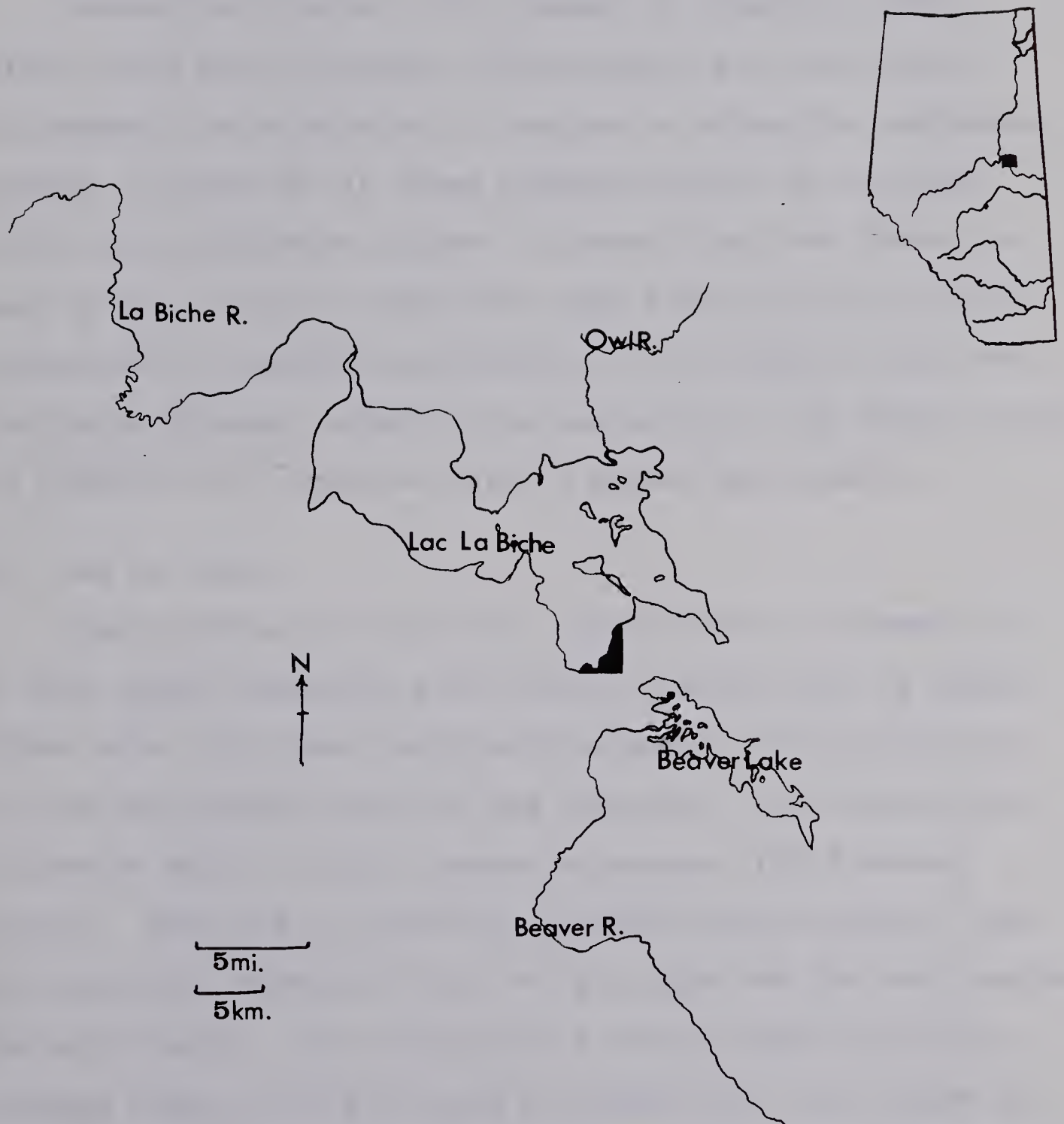
Their division of the limnological regions of the Western Canadian Plains puts these two bodies of water in the Forest Zone of Freshwater Lakes. Westgate (pers. comm., U. of A., 1967) has evidence to place the age of these lakes somewhere between 11,500 and 12,000 years. The general northwest-southeast orientation of most of the lakes in this region is believed to be due to the reactivation of a dormant glacier during the latest ice retreat.

Beaver Lake drains via the Beaver River into the Churchill drainage and hence to the Hudson Bay. Beaver Lake is without an inlet as such, but maintains a near constant level throughout the summer period and is probably fed by a number of underground sources.

Lac La Biche has one major inlet, the Owl River, which drains an area to the northeast of Lac La Biche. The lake is drained by the La Biche River, which flows into the Athabaska River and hence via the Mackenzie River to the Arctic. The two lakes are separated by 3 1/4 kilometers (2 1/4 miles) and a very low height of land (Fig. 1). Lac La Biche is 586 meters above sea level and Beaver Lake is 611 meters above sea level.

The town of Lac La Biche is situated on the south shore of Lac La Biche. It is the only large center in the area and has a population of about 1,800. The surrounding area is sparsely populated, the only other hamlet near the study area being Plamondon, situated on the southwest shore of Lac La Biche. The area immediately around Lac La Biche supports several farming families. Large numbers of Metis and Indians

Figure 1. Map of study area. (Inset with darkened area shows location of large scale map.) Dark area along southeast margin of Lac La Biche is location of the town of Lac La Biche.



live in the region. Economic activity in the area mainly involves mixed farming, commercial fishing, lumbering, fur farming and trapping, and government welfare support. Most of the region is uncultivated.

Vegetation consists of a canopy of trembling aspen, birch, jack pine, tamarack, white spruce and black spruce. In general the underbrush in regions of extensive coniferous growth is light but in areas composed mostly of deciduous forest the underbrush becomes so heavy that foot travel in most areas is nearly impossible away from the trails. The underbrush is composed principally of pin cherry, wild rose, red osier dogwood, Labrador tea and willow. The forest floor is covered with extensive mats of mosses and grasses.

2. Lac La Biche

Lac La Biche is one of the larger lakes in Alberta, in a size range comparable with bodies of water such as Lesser Slave Lake, Cold Lake and Winnifred Lake, all of which are in the same general area of the province. The surface area of Lac La Biche is 229.9 square kilometers (88.8 square miles). The lake is naturally divided into two basins, the west portion, referred to as the Big Lake and the east portion as Little Lake. The Little Lake is fairly shallow, with a maximum depth of 42 feet, and is dotted with ten islands of varying size. This portion of the lake in particular provides extensive habitat for waterfowl. The white pelican, Pelicanus erythrorhynchos Gmelin, exists in relatively large numbers on the lake and uses the fishes from the lake as a food source. Salt and Wilk (1958) report a nesting colony of pelicans on

Figure 2a. Shoreline of Lac La Biche, note very low slope.

Figure 2b. Shoreline of Beaver Lake, note steep nature of banks.



the lake but none were observed nesting during the study. The common loon, Gavia immer (Brunnich), is common on the lake as are the red-necked and horned grebes, Podiceps grisigena Reinhardt, and P. auritus Gmelin. The double-crested cormorant, Podiceps grisigena (Lesson) and great blue heron, Ardea herodias L. were observed. Numerous ducks were found nesting in the abundance of reeds, Scirpus sp., around the shores of the lake. The most common avian residents of the lake were the California gull, Larus californicus Lawrence; the ring-billed gull, L. delawarensis Ord and the common tern, Sterna hirundo L., all of which had breeding colonies on the more inaccessible islands of the lake.

Lac La Biche has an extensive littoral area as evidenced by the low profile shoreline and extensive low sandy beaches (Fig. 2a). This abundance of littoral area is due mostly to the shallow slope of the lake basin. This general shallow basin is shown in the hypsographic curve of the lake (Fig. 3a).

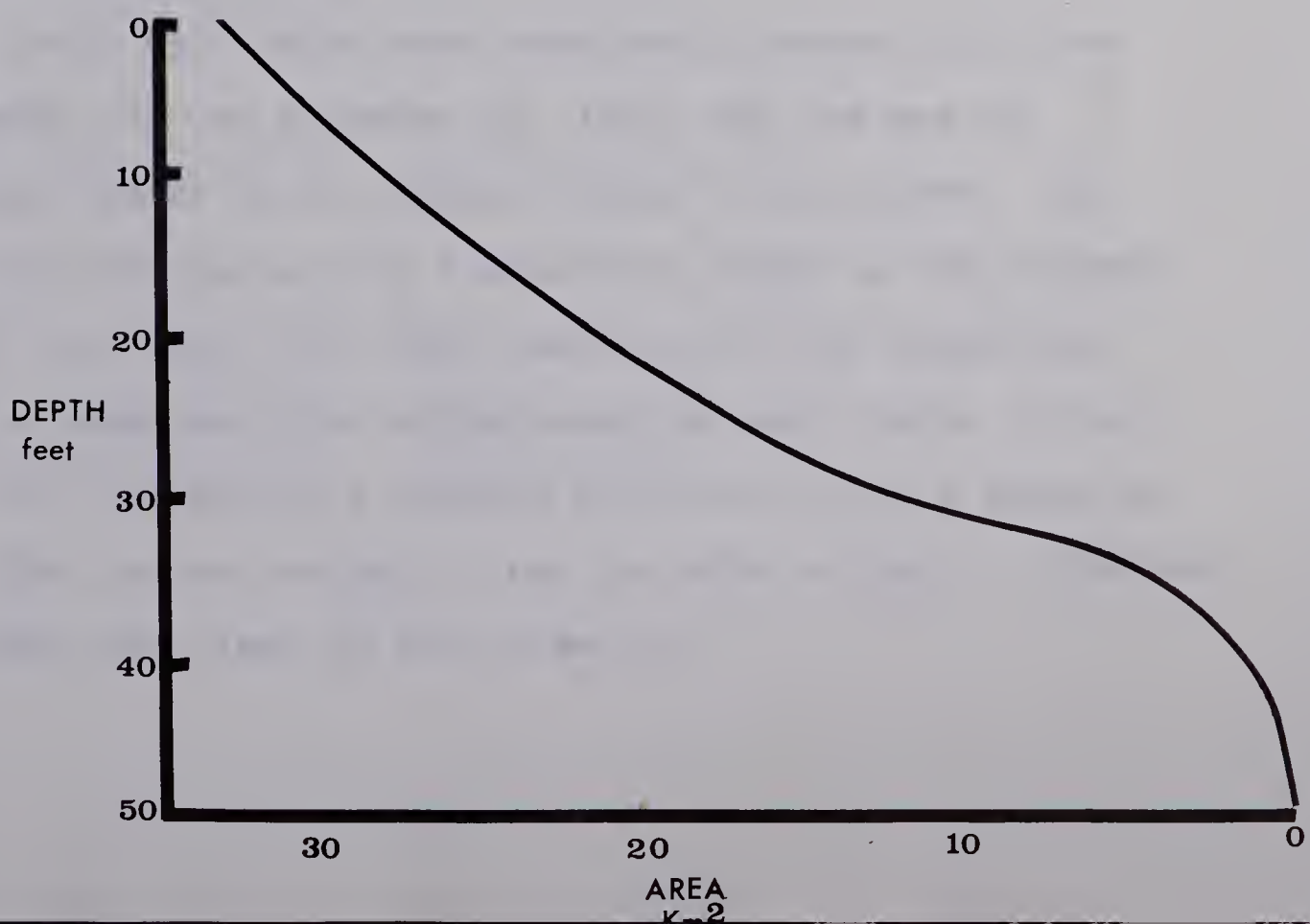
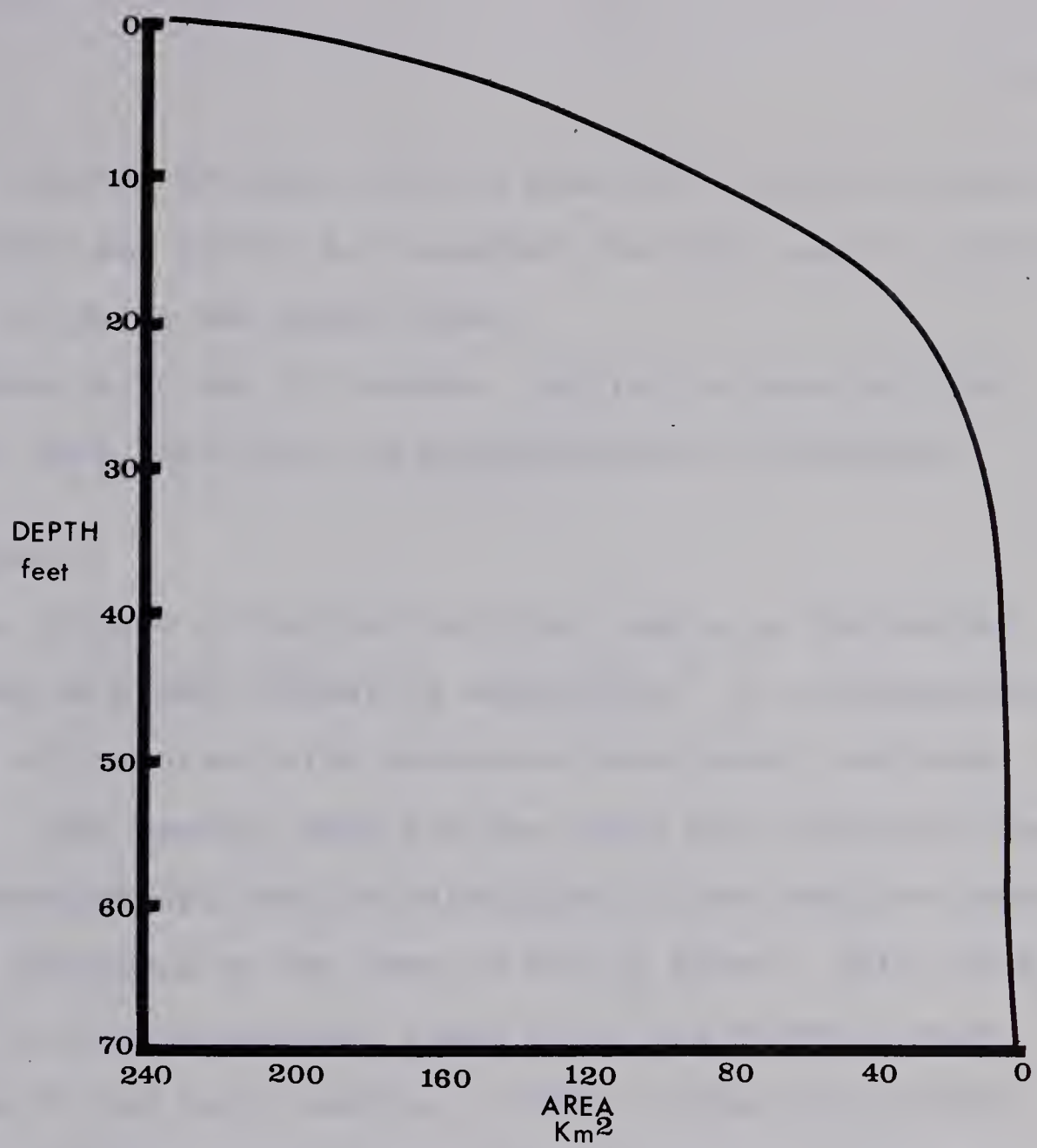
3. Beaver Lake

Beaver Lake is much smaller than Lac La Biche, having a surface area of only 33.0 square kilometers (12.8 square miles). It is long and narrow and is naturally divided into two basins, separated by a shallow narrows. The slope of Beaver Lake is quite steep, as evidenced by the lack of beach and the steep shoreline (Fig. 2b). The hypsographic curve (Fig. 3b) also illustrates the rapid drop-off and relatively flat bottom.

The lack of extensive littoral and shore regions makes Beaver Lake only marginal habitat for most aquatic birds.

Figure 3a. Hypsographic Curve of Lac La Biche.

Figure 3b. Hypsographic Curve of Beaver Lake.



Several species of ducks and the great blue heron are present on the lake and grebes are abundant, but the lake is generally lacking in gulls and shore birds.

Beaver Lake has 17 islands, varying in size but for the most part less than one hundred meters in diameter.

4. Climate

The climate of the Lac La Biche region is defined by the Atlas of Canada (Anon) as sub-arctic. It is characterised by long cold winters with extensive snow cover, and warm summers. The weather data for the study were obtained from the meteorological station maintained by the Dominion Department of Transport at the town of Lac La Biche. Daily observations on wind direction, cloud cover and rainfall were recorded at the field station. Table I shows the monthly temperature means, total rainfall and snowfall. Table II shows the monthly temperature means for June, July and August from 1945 to 1966.

In 1965, both lakes were completely covered with ice by November 13. On December 28, 1965, the ice was 50 centimeters thick in the central areas of the lakes. In early March the ice was 80 centimeters thick in the exposed areas of the lakes. In early February of 1965 subnivean melting of snow and ice had occurred in many places on the lakes. The ice was in a candled condition on both lakes on May 9. The ice was melted in Lac La Biche on May 11, 1966 and Beaver Lake was clear of ice on May 10.

Table I. Some Meteorological Conditions at Lac La Biche.

Month	Temperature (°F)		Snowfall	Precipitation (inches)	
	High	Low		Total	Depth of Snow
1965					
May	73	23	nil	2.69	nil
June	82	31	nil	4.32	nil
July	87	41	nil	2.22	nil
August	84	36	nil	4.17	nil
September	71	17	Tr	1.05	nil
October	71	23	nil	.25	nil
November	54	-22	8.9	.89	9
December	44	-40	5.8	.58	10
1966					
January	24	-55	13.6	1.36	22
February	46	-32	2.1	.21	18
March	not available				
April	58	0	8.5	.85	nil
May	82	29	nil	2.33	nil
June	82	31	nil	1.29	nil
July	85	41	nil	2.08	nil
August	84	34	<u>nil</u>	<u>5.57</u>	nil
Annual Mean, June to June, 29.4			Total 38.9	29.06	

Table II. Mean Monthly Temperatures °F, at Lac La Biche,
Summer Months, 1945-1966. (From Department of
Transport, Lac La Biche)

	<u>June</u>	<u>July</u>	<u>August</u>
1945	56.1	63.2	60.7
1946	56.8	64.1	60.6
1947	55.6	63.0	54.8
1948	62.2	62.0	58.3
1949	56.0	62.7	63.0
1950	59.5	64.0	57.1
1951	54.4	62.3	59.1
1952	57.4	61.4	59.1
1953	56.4	61.8	61.7
1954	55.7	62.5	59.0
1955	59.2	62.9	61.2
1956	58.5	62.2	60.8
1957	55.2	60.7	57.7
1958	57.2	63.7	63.2
1959	54.6	62.3	54.6
1960	54.1	63.2	58.9
1961	62.3	61.4	61.7
1962	55.7	58.2	58.7
1963	56.2	63.3	60.8
1964	55.3	63.4	57.3
1965	55.2	60.7	56.0
1966	54.2	57.3	57.3

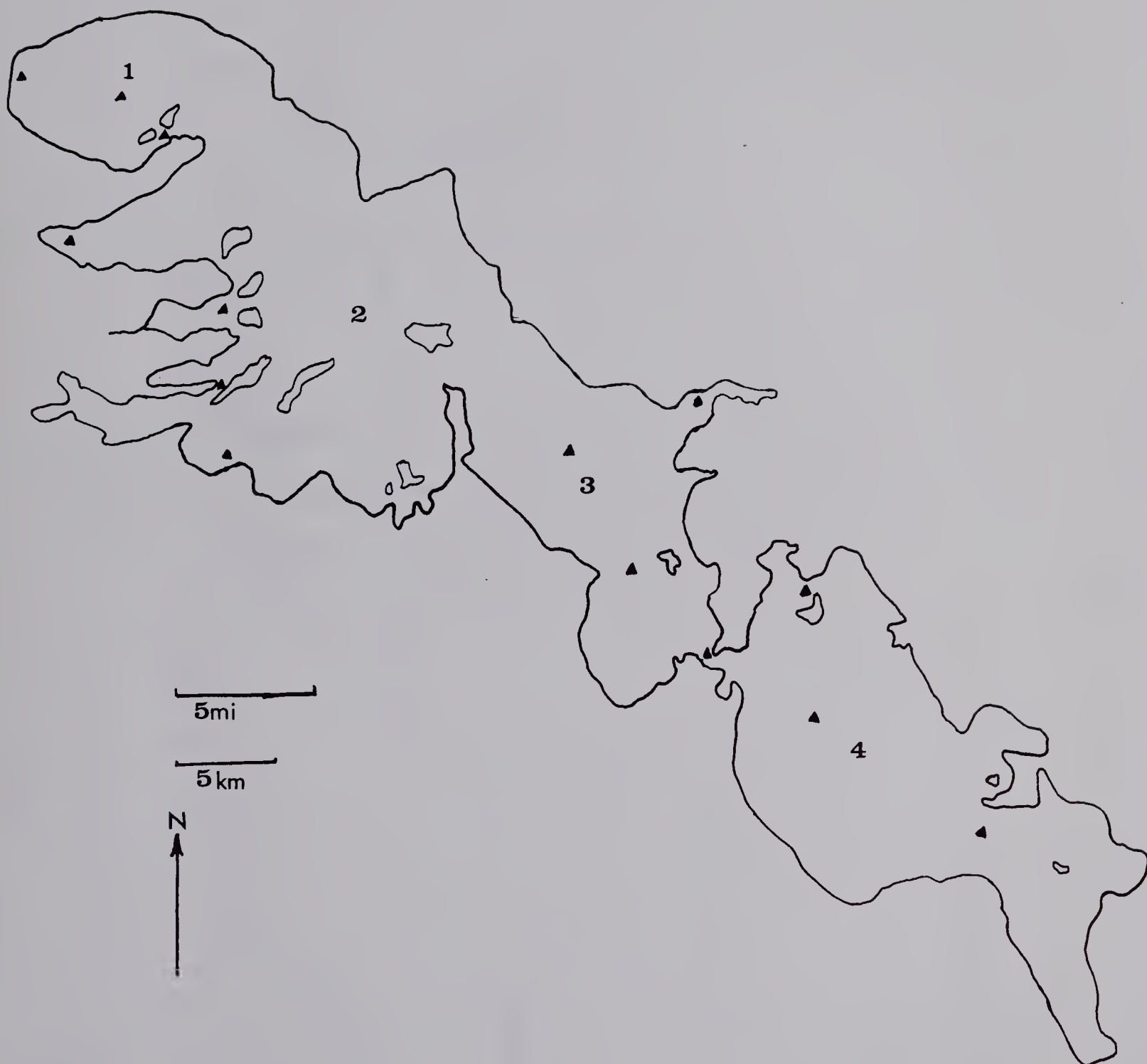
III MATERIALS AND METHODS

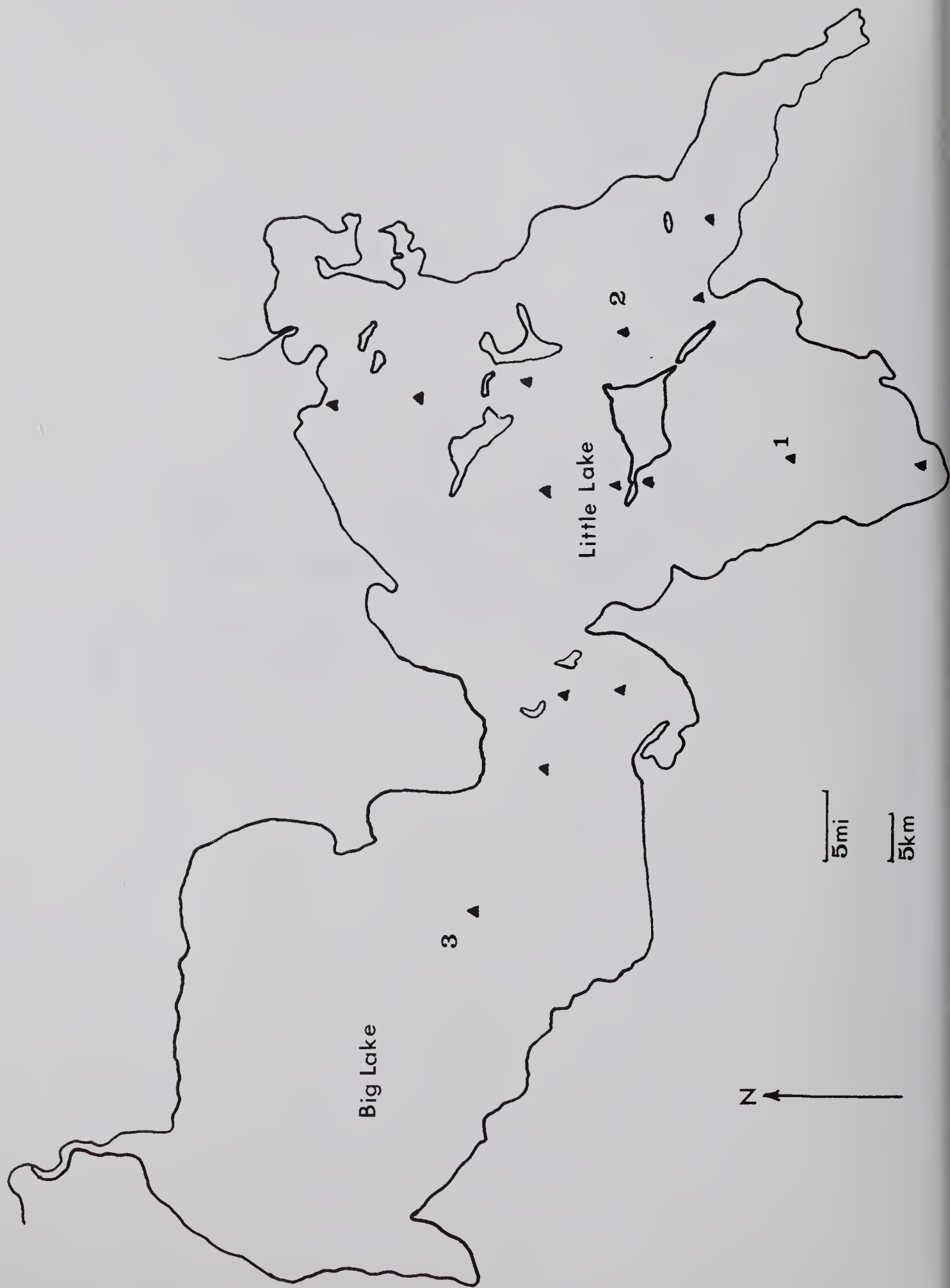
Data were collected during the period of May 20, to September 11, 1965. During the following winter, visits were made to the lakes at approximately monthly intervals when ice cover and weather conditions made it possible to venture onto the lakes. In general, lakes in the area are unsafe for vehicles until mid-December and by late February overflow, sub-nivean melting of ice and deep snow cover make travel impossible on the lake by wheeled vehicle. A field station was again established in the town of Lac La Biche on May 16, 1966 and was used as a base of operations until September 15, 1966.

Four sampling stations for physical and chemical measurements were established on Beaver Lake and three on Lac La Biche (Figs. 4 and 5). These were selected to attempt to take into consideration the natural basins of each lake. It was thought that sampling at these sites would elucidate any differences occurring between basins in the lakes. During the summer of 1965 it was found that stations 2 and 3 on Beaver Lake were almost identical to station 1 and as a result during the remainder of the study these stations were abandoned except when initial results warranted a more complete examination.

During the summer of 1965 the general study scheme was to spend one week on Beaver Lake doing a routine series of collections and measurements followed by a week on Lac La Biche doing the same set of collections and measurements.

Figure 4. Sampling Stations on Beaver Lake (- denotes a bottom sampling station; numbers indicate a plankton and physico-chemical sampling station).





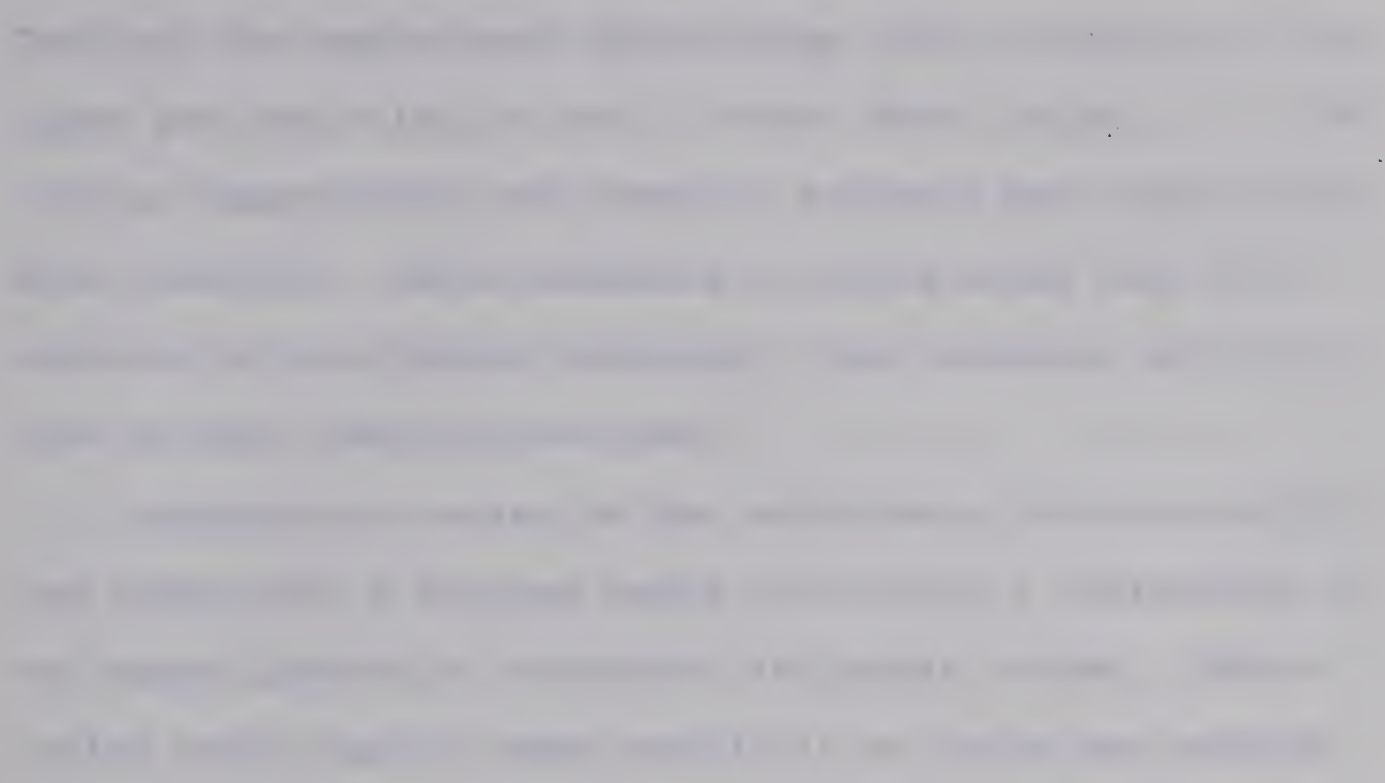


Figure 5. Sampling stations on Lac La Biche.

(▲ - denotes a bottom sampling station;
numbers indicate plankton and physico-
chemical sampling stations).

The next two weeks were spent doing other sampling on the lakes and assisting in the La Biche River survey. In 1966 routine temperature and chemical analyses were made weekly when possible. Extra sampling in these areas was done whenever it was deemed necessary, for instance, when the time of fall overturn was near.

Temperature series of the water were taken on each of the lakes with a Whitney Model TC5 electric thermometer at one meter intervals throughout the water column. These series were usually taken weekly in at least one station and a complete set of readings taken biweekly on each lake. In 1965 dissolved oxygen was determined by the Miller method (Miller, 1914). In 1966 an unmodified Winkler method (Winkler, cited in Welch, 1948) was used. This was done at the site when weather conditions allowed for accurate titration but when windy conditions were encountered the samples were fixed and analyzed within 12 hours in the field laboratory. pH determinations were made at the same time the dissolved oxygen sample was taken. This was done with a Hellige color disc comparator using Cresol Red B Indicator and Phenolphthalien Blue Indicator solutions prepared by Hellige Inc. All sub-surface samples were taken with a two liter Kemmerer bottle. At monthly intervals samples from each lake were analyzed for total alkalinity, calcium hardness, total hardness, nitrates, nitrites, total phosphate, total sulphate, turbidity and % transmittance with a Hach model DR-EL Portable Water Engineer's Laboratory. Samples were taken from the lake, transferred to a 250 ml glass-

stoppered bottle and taken directly to the field station where they were analyzed.

In August, 1966, a series of six bottom samples was taken from each lake and the series from each lake thoroughly mixed. A subsample was taken from each of these and submitted to the Provincial Soils Testing Laboratory, Edmonton, Alberta for examination as to nitrogen, phosphorus, potassium, sulphate, free lime content and pH.

Plankton samples were taken monthly in 1965 and biweekly in 1966. In 1965 a two-liter sample was taken from each station at the surface, a depth of one meter and a depth of five meters. These samples were taken to the field station and centrifuged with a Foerst plankton centrifuge. The seston was preserved in five per cent formalin and retained to be dried and ashed later to determine organic content. The sample was filtered through a Millipore filter of pore diameter 0.8 microns, dried at 100 C for 12 hours, as recommended by Lovegrove (1966) and ashed at 600 C for one half hour as suggested by Kerekes (1965). In 1966 zoo-plankton samples were taken with a plankton net since it was found that the centrifuge technique used in 1965 badly damaged the plankters. While the problems inherent in sampling plankton with a net are many and varied, as shown by Ricker (1932, 1938), portability and availability of nets made them desirable for sampling in this case. While forsaking some accuracy, representable samples were obtained and the specimens were acquired in an easily identifiable form. All plankton net hauls were taken vertically from eight meters

to the surface. Two nets were used over the length of the summer, one with a 25 cm diameter opening and one with a 12.5 cm diameter opening. All plankton nets were of number 20 bolting silk.

Samples taken with the plankton net were counted using a Sedgwick-Rafter counting cell. Two one ml samples of the concentrate were counted completely. This gives the desired degree of statistical validity to the results as shown by Kutkuhn (1958).

The nanoplankton and larger phytoplankton were sampled by filtering a known quantity of water from each of the surface, a depth of one meter and a depth of five meters through a Millipore filter system using filters of pore diameter 0.8 microns. The filters were then cleared with cedar wood oil and mounted directly onto glass slides. The technique used was that of McNabb (1958, 1960).

Once during the summer of 1966 samples were taken at six hour intervals over a 24-hour period on each lake. These were taken with a closing plankton net. Samples were from a depth of 0-1 meter; 1-3 meters; 3-5 meters and 5-8 meters.

Bottom samples were taken monthly throughout the ice-free periods of 1965 and 1966. These were taken with a six inch Ekman dredge with inside measurements of 15.2 cm by 15.2 cm. Bottom sampling stations were established at the points designated in Figures 4 and 5. Upon obtaining a sample of the bottom, it was transferred to a pail and upon return to shore, was washed through two screens constructed

after Rawson's (1930) design. One screen had 560 meshes to the square inch and the second had 700. In 1965 the mud was washed from the sample by dipping pails of water out of Beaver Lake and pouring this onto the sample. In 1966 a stream of water from a hose was used. This resulted in a more thorough washing and did not seem to affect the organisms adversely with the possible exception of some lumbriculid oligochaetes. The organisms were removed from the screens with forceps and transferred to 10 per cent formalin for later examination. In the laboratory the bottom fauna was sorted into families, counted and weighed on a Mettler analytical balance to 0.01 grams.

Fishes were captured at various times throughout the study. They were caught by gill nets ranging in size through 3/4 inch stretched mesh to 5 1/2 inch stretched mesh, by angling equipment, seines and rotenone fish toxicant. Fishes obtained were weighed with a spring balance, measured, the sex of each fish was determined and a scale sample was taken. Age of all fishes examined was determined by counting the annuli on scales from each fish.

At various times throughout the study qualitative samples, particularly from the littoral areas, were taken. This involved the use of dip nets, a Birge cone net, plant hooks and a fifteen foot commonsense seine. Organisms obtained were preserved in 10 per cent formalin for later study and identification.

All organisms obtained were identified as completely as possible. Several different keys were used, including

Brooks (1957) for Daphnia; Carl, Clemens and Lindsey (1959) for fishes; Edmundson (1965) for many invertebrates; Hubbs and Lagler (1958) for fishes; Moore (1964, 1966) for Hirudinea; Pennak (1953) for many invertebrates; Pennak (1963) for cyclopoid copepods; Prescott (1964) for algae and Usinger (1963) for aquatic insects.

IV PHYSICAL CHARACTERISTICS

1. Morphometry

The greatest morphometric difference between Beaver Lake and Lac La Biche is size (Table III). Lac La Biche has an area 6.9 times as great as that of Beaver Lake. The greater size makes Lac La Biche more susceptible to wind action because the maximum effective length is over twice that of Beaver Lake. Both lakes are oriented in a NW-SE direction, in line with the prevailing winds of the area. Figure 2a illustrates the sandy, sloping shore areas on the lee side of Lac La Biche formed by action of the prevailing winds over a long period of time.

While the maximum depth of Lac La Biche is 7.7 meters more than that of Beaver Lake, the mean depths, which Rawson (1955) considered the most important factor in lake typology, are almost identical; 6.9 meters for Beaver Lake and 7.4 meters for Lac La Biche. This would put both lakes in the eutrophic class as defined by Thienemann (1927).

Beaver Lake has a shoreline development of 4.18, much greater than the largest reported by Hutchinson (1957) in Wisconsin lakes. Hutchinson also pointed out that elongation of a basin is generally much more important in giving a high value for shoreline development than mere sinuosity of shoreline. Beaver Lake is a long, almost rectangular lake in general outline compared to Lac La Biche which is composed of two more or less circular basins. Lac La Biche has a shoreline development of 1.99.

Rawson (1960a) considered the ratio of perimeter to area a useful measurement for comparing lakes of different sizes. In Beaver Lake this ratio is 2.59 while in Lac La Biche it is 0.70 which indicates a large degree of difference, even more than is shown by shoreline development.

Lac La Biche and Beaver Lake are similar in volume development: 1.41 to 1.36.

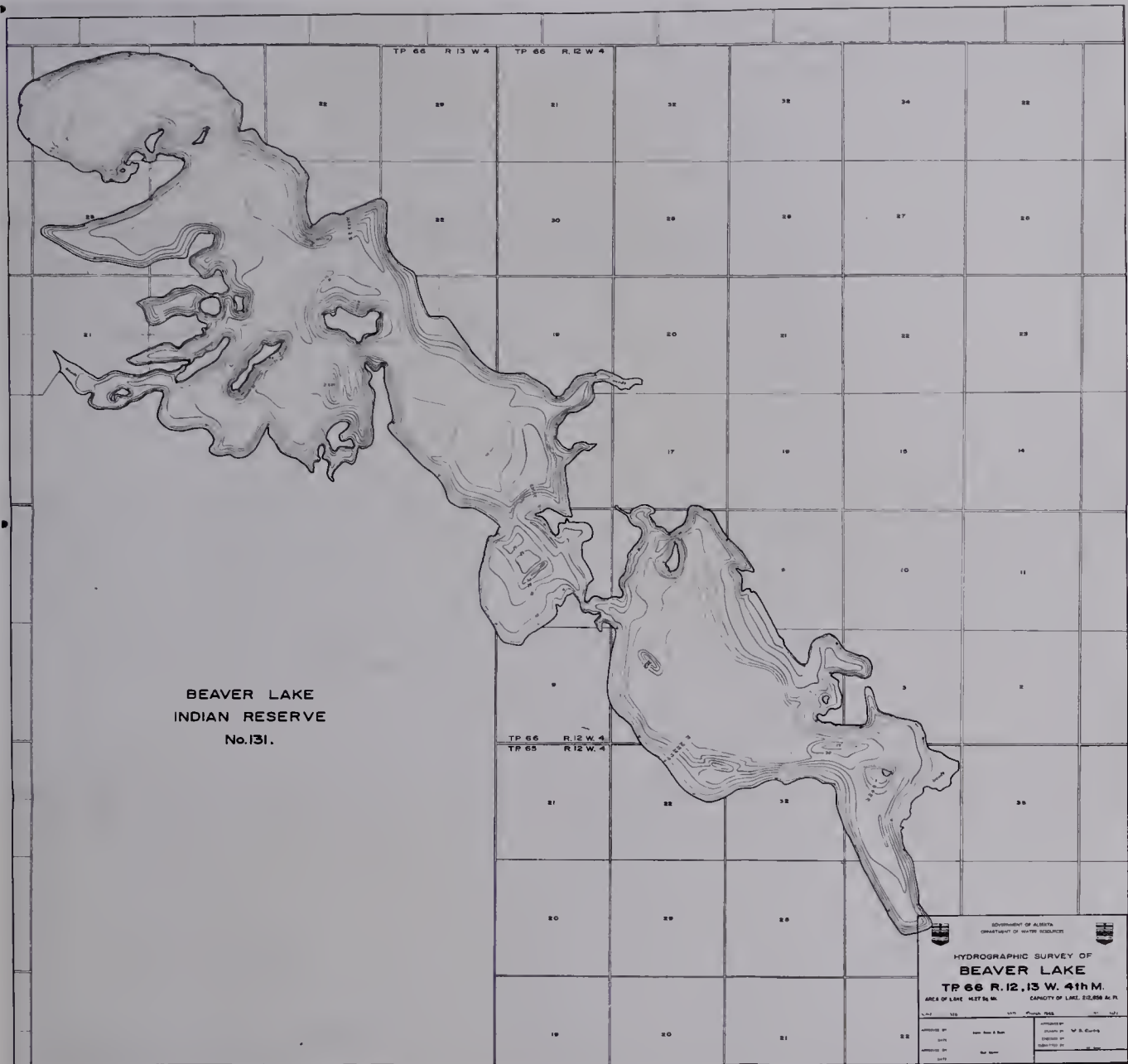
Beaver Lake is separated into four basins along the length of the lake (Fig. 6). Three are broadly connected while the southernmost basin is nearly separated from the others, being connected only by a shallow narrows. Lac La Biche is made up of two basins, a larger deep one and a shallow one with numerous islands in it (Fig. 7).

The general profiles of the lake bottoms differ quite considerably (Figs. 3a, 3b, 6 and 7). Beaver Lake has very little littoral area, but has a very level bottom throughout the whole of the lake. Lac La Biche has extensive shoreline shallow areas. The flat bottom of Beaver Lake is due in large part to the extensive sedimentation that has occurred in the lake. Analysis of echo soundings showed sediments to have accumulated to a depth of four meters in some places.

The water level in both lakes remained nearly constant during the study period. In Lac La Biche a small rise in levels was noted during midsummer when the outlet stream, the La Biche River, became choked with aquatic vegetation. There has been a marked rise in the water level of Beaver Lake from former years. The remains of trees on what was once the

Figure 6. Bottom Contour Map of Beaver Lake*.
Contour Lines at five foot intervals.

* Constructed by the Water Resources
Branch, Government of Alberta, 1965.



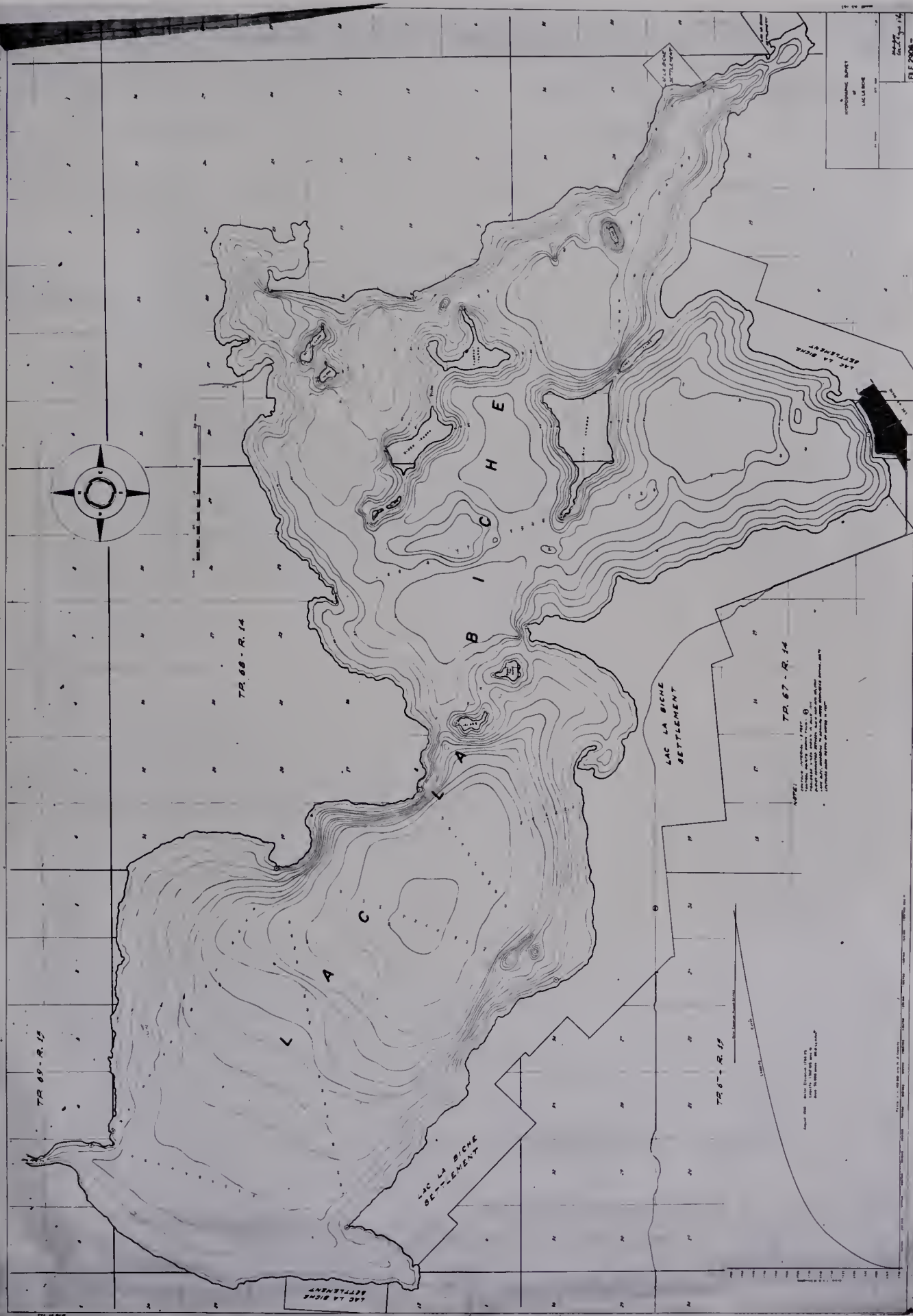
BEAVER LAKE
INDIAN RESERVE
No. 131.

TP 66 R. 12 W. 4
TP 65 R. 12 W. 4

GOVERNMENT OF ALBERTA DEPARTMENT OF WATER RESOURCES	
HYDROGRAPHIC SURVEY OF BEAVER LAKE TP 66 R. 12, 13 W. 41h M. AREA OF LAKE 1427 Sq. MI. CAPACITY OF LAKE 212,850 AC. FT.	
DATE 1955	BY W. S. Curtis
DATE 1955	BY W. S. Curtis
DATE 1955	BY W. S. Curtis

Figure 7. Bottom Contour Map of Lac La Biche*.
Contour Lines at five foot intervals.

* Constructed by the Water Resources
Branch, Government of Alberta, 1960.



HYDROGRAPHIC SURVEY
OF
LAC LA BICHE
1927
FILE 2008

NOTE:
The map is a reproduction of the original map.
The original map is in the possession of the
Government of Canada.

Source: Hydrographic Survey of Canada
1927
Scale: 1:50,000
Projection: UTM
Datum: NAD 83

Figure 8a. Submerged trees in Beaver Lake indicating recent rise in lake level.

Figure 8b. Submerged trees in Beaver Lake indicating recent rise in lake level.



shoreline are seen in many regions around the lake and now are found in up to one meter of water (Figs. 8a and 8b). It is unknown when this rise of lake level occurred but it is assumed to be since 1951. Aerial photographs of the area taken at about that time show that what are now islands were then connected to the shore.

2. Temperature

Both Beaver Lake and Lac La Biche have a dimictic temperature cycle. From the limited data available it can be concluded that winter is the most extensive period of stratification. During the winter period both lakes were stratified for nearly as long as they were covered with ice (Figs. 9 and 10).

During the summer the whole of the deeper regions of Beaver Lake stratify, while only the Big Lake of Lac La Biche stratifies. The other portion of Lac La Biche is as deep as Beaver Lake but it does not stratify. This is probably because the extensive areas of open water make wind mixing easy. Mixing is no doubt further enhanced by the shape of the basin. A shallow sloping bottom allows for more complete mixing than a steep sloping basin such as is found in Beaver Lake.

The thermocline was of longer duration in both lakes in the summer of 1965 than in the summer of 1966 (Figs. 9 and 10). Several days of cold, windy, inclement weather in mid-August of 1966 were sufficient to cause the fall overturn to take place prematurely. It is believed that the summer of 1966 was the more atypical of the two. In June, July and

Table III. Morphometric Measurements of Beaver Lake and
Lac La Biche.

	<u>Beaver Lake</u>	<u>Lac La Biche</u>
Maximum Depth	15.2 meters	22.9 meters
Maximum Length	14.4 km	32.2 km
Maximum Effective Length	8.1 km	17.7 km
Maximum Width	2.8 km	15.6 km
Maximum Effective Width	2.8 km	9.7 km
Mean Width	2.14 km	7.14 km
Mean Depth	6.9 meters	7.4 meters
<u>Mean Depth</u>		
Maximum Depth	.454	.381
Shoreline Length	85.5 km	161.0 km
Shoreline Development	4.18	1.99
Volume	.232 km ³	1.929 km ³
Volume Development	1.362	1.41
Surface Area	33.05 km ²	229.90 km ²
<u>Perimeter</u>		
Area	2.59	.70

Figure 9. Seasonal temperature cycle in Beaver Lake from July, 1965 to September, 1966. Area between dotted lines indicates approximate region of thermocline.

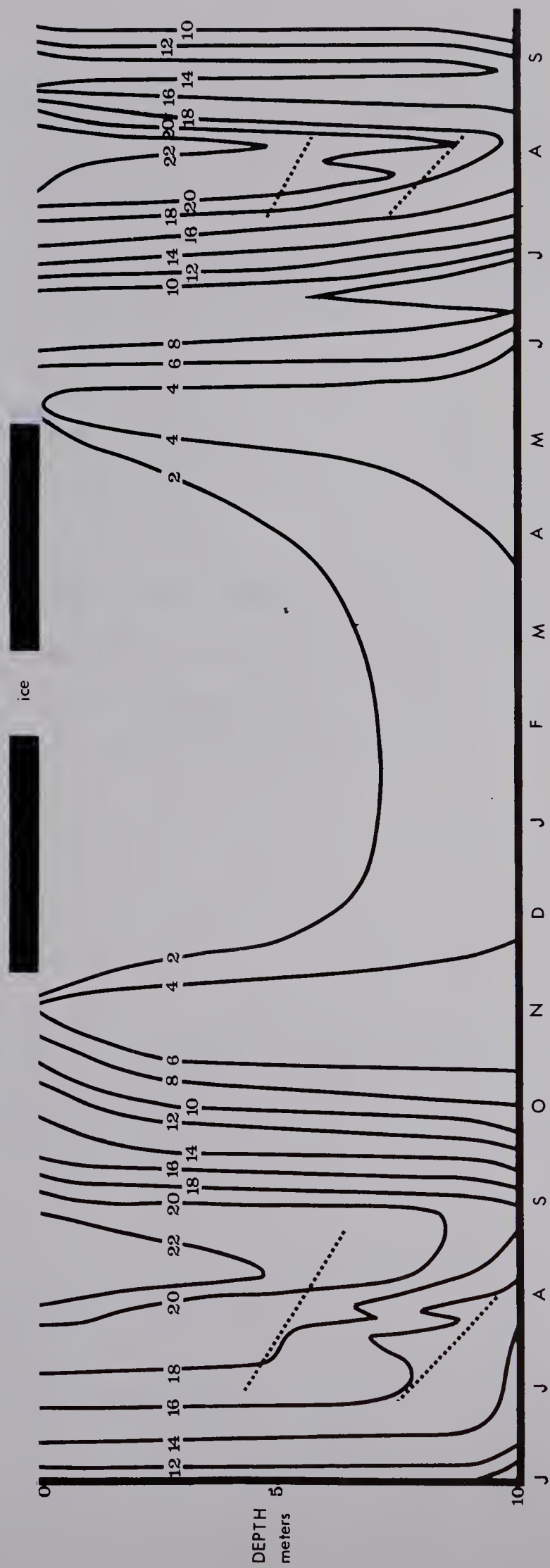
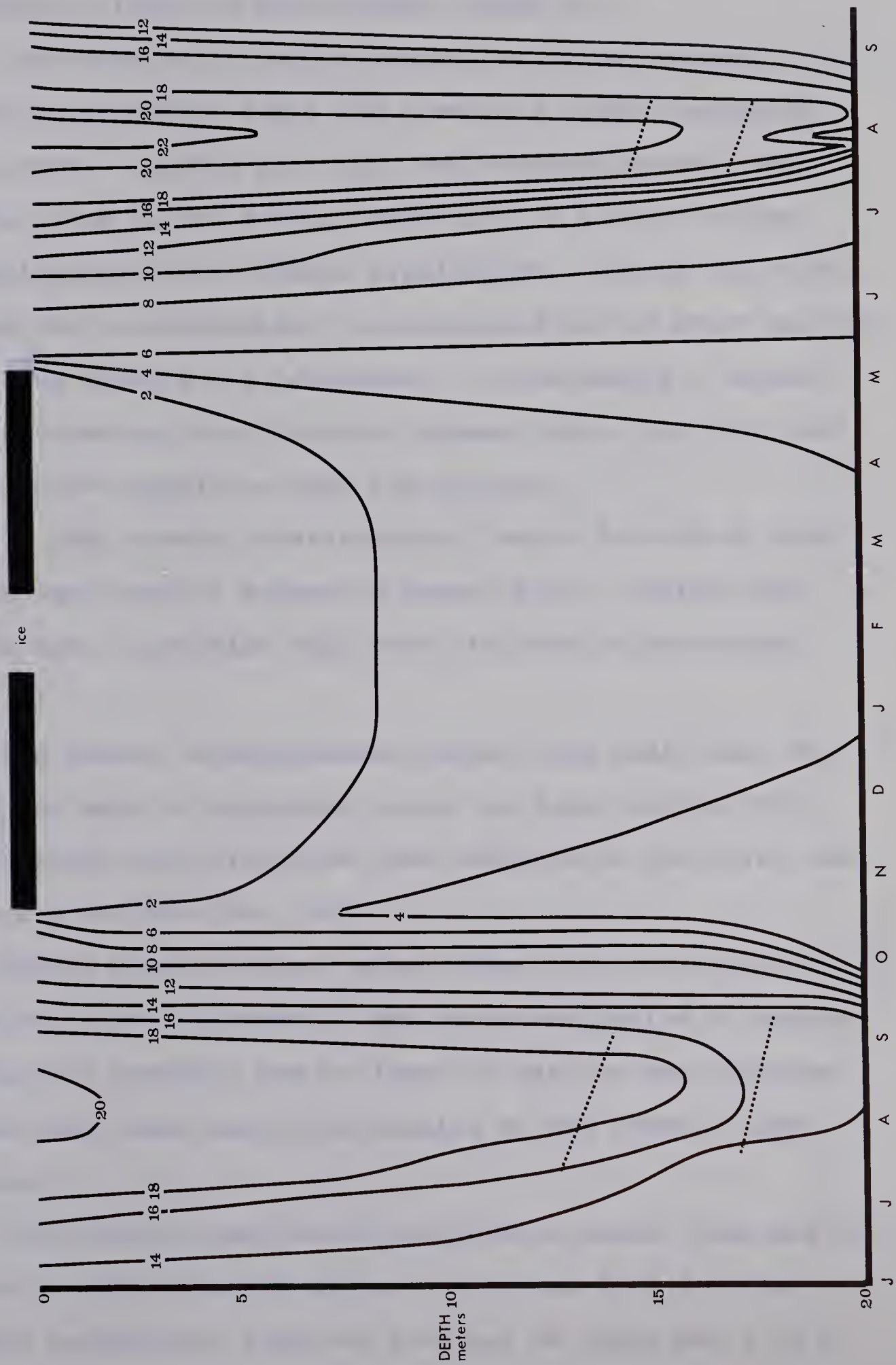


Figure 10. Seasonal temperature cycle in Lac La Biche from July, 1965 to September, 1966. Area between dotted lines indicates approximate region of thermocline.



August of 1966 the monthly mean air temperatures were low compared to those of other years (Table II).

The thermocline begins during the spring warming period at a shallow depth and gradually sinks throughout the summer. In both the lakes the thermocline was most stable close to the bottom, resulting in a large volume of epilimnion and a reduced hypolimnion. During the stable period the stratification is maintained during short periods of strong winds and cold weather. Occasionally a second less noticeable stratification appears above the first and sinks quite rapidly to join the original.

In 1965 summer stratification lasted from early June to the last week of August in Beaver Lake. During 1966 Beaver Lake stratified only from mid-June to mid-August (Fig. 9).

The summer stratification lasted from early June to the first week in September in Lac La Biche during 1965. Lac La Biche was stratified from mid-June to the first week in August in 1966 (Fig. 10).

Spring overturn lasts about three months and fall overturn about two months. The extensive period of spring overturn is probably due at least in part to the latitude of the area which makes the warming of the lakes a slow process.

The maximum temperature recorded in Beaver Lake was on August 8, 1965 when the surface water was 25.7 C. The maximum temperature recorded from Lac La Biche was 23.4 C on August 4, 1966.

3. Turbidity

In general the lakes must be regarded as being very clear. There was little variation in the turbidity throughout the sampling period. The only occasions on which the turbidity rose above 20 Jackson Turbidity Units (JTU) was on August 8, 1965 at station 4 in Beaver Lake when in the hypolimnion it was 52 JTU. This may have been a result of a stirring in the hypolimnion. On the same date at the surface of station 4 in Beaver Lake a turbidity reading of 29 JTU was recorded. This latter reading was probably due to a bloom of the cyanophyte, Lyngbya sp., which was evident in this region of the lake on that date. A dissolved oxygen reading on the same evening on that part of the lake was over 150% saturation at the surface due to the excessive phytoplankton bloom.

Secchi disc measurements were taken periodically throughout the study, but little difference was found between the lakes. The use of a disc of this nature is of value only in the very crudest of comparisons in any event. Welch (1948) pointed out that the Secchi disc is not a measurement of light penetration but only a rough index of visibility. Secchi disc readings taken periodically throughout the study period varied from 1.5 to 2.0 meters in both lakes. No apparent reason can be assigned to the variations. In all likelihood they were closely linked to the vagaries of the weather of a particular day.

Table IV. Per cent transmittance and turbidity readings
from Lac La Biche and Beaver Lake.

Date	Station	Depth (meters)	% transmittance	Turbidity (JTU)
Beaver Lake				
1/6/65	2	0	99	0
16/6/65	1	0	95	
16/6/65	1	8	95	
24/6/65	1	0	97	8
24/6/65	3	0	97	8
22/7/65	3	0	98	8
22/7/65	3	9	96	17
22/7/65	4	0	98	10
8/8/65	1	0	99	5
8/8/65	1	9	85	52
8/8/65	4	0	94	29
26/8/65	1	0	97	6
7/9/65	1	0	98	3
7/9/65	4	0	99	2
19/5/66	1	0	97	12
14/6/66	1	0	98	8
14/6/66	4	0	98	8
4/7/66	1	0	99	5
4/7/66	4	0	95	19
15/8/66	1	0	97	15
5/9/66	1	0	98	8
Lac La Biche				
4/6/65	1	0	99	5
12/6/65	2	0	99	2
28/6/65	1	0	99	5
28/6/65	2	0	98	10
28/6/65	3	21	99	5
28/7/65	2	0	98	8
28/7/65	3	0	99	2
28/7/65	3	18	99	5
18/8/65	3	0	94	20
18/8/65	3	18	99	5
18/8/65	2	0	95	2
19/5/66	3	0	99	5
16/6/66	3	0	97	15
16/6/66	2	0	98	10
4/7/66	3	0	98	8
4/7/66	3	18	99	5
15/8/66	3	0	99	3
5/9/66	3	0	97	11

V CHEMICAL CHARACTERISTICS

1. Dissolved Oxygen

The dimictic nature of both lakes is shown by the oxygen cycles (Figs. 11 and 12). Periods of severe stagnation are evident in the lower waters of the lakes in both the summer and winter stratifications. Unfortunately, it was not possible to obtain data for the later portions of the ice-covered periods. It is assumed that much lower oxygen conditions existed, at least in the bottom layers of the lakes. The supersaturated conditions in the surface waters, particularly in Beaver Lake, were presumably due to oxygen production by phytoplankton blooms. It is noteworthy that supersaturation was not recorded in either lake during the summer of 1966.

The duration of oxygen depletion in the hypolimnion during the summer of 1966 was considerably shorter than in the summer of 1965 in both lakes. This corresponds to the variation in temperature conditions in these two periods.

The maximum dissolved oxygen content recorded during the study was 16.2 ppm, 150% saturation, on August 8, 1965. This value was found only in the southernmost basin of Beaver Lake. It occurred in the surface waters during an extreme phytoplankton bloom. It was preceded by an extremely long period of hot calm weather.

No hydrogen sulphide was found in the lake waters during the period of the study, so one can assume that there was always some dissolved oxygen present in the lakes, although at times the amount was very minute (less than one ppm).

Figure 11. Seasonal cycles of dissolved oxygen in
Beaver Lake from June, 1965 to September,
1966.

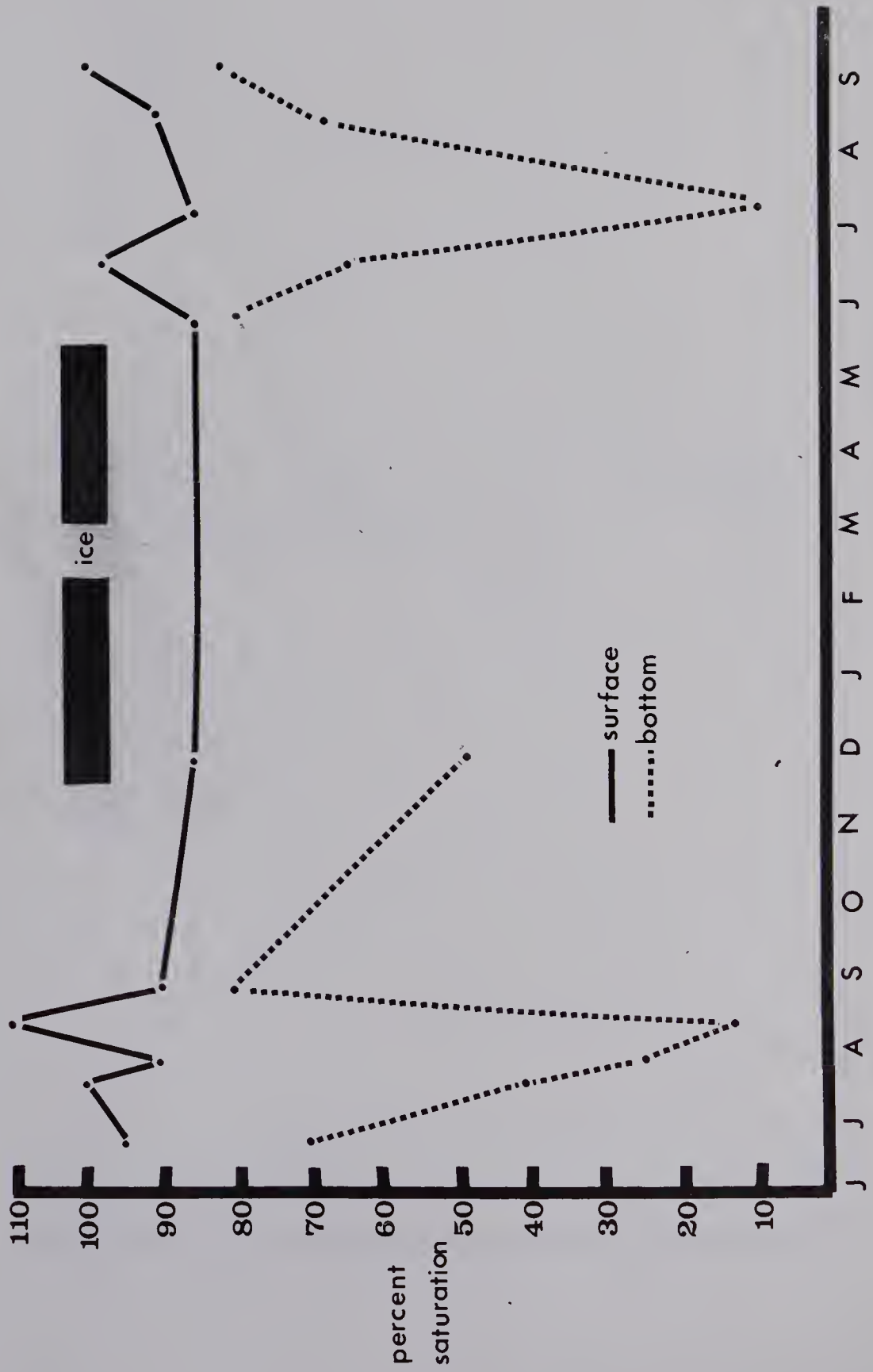
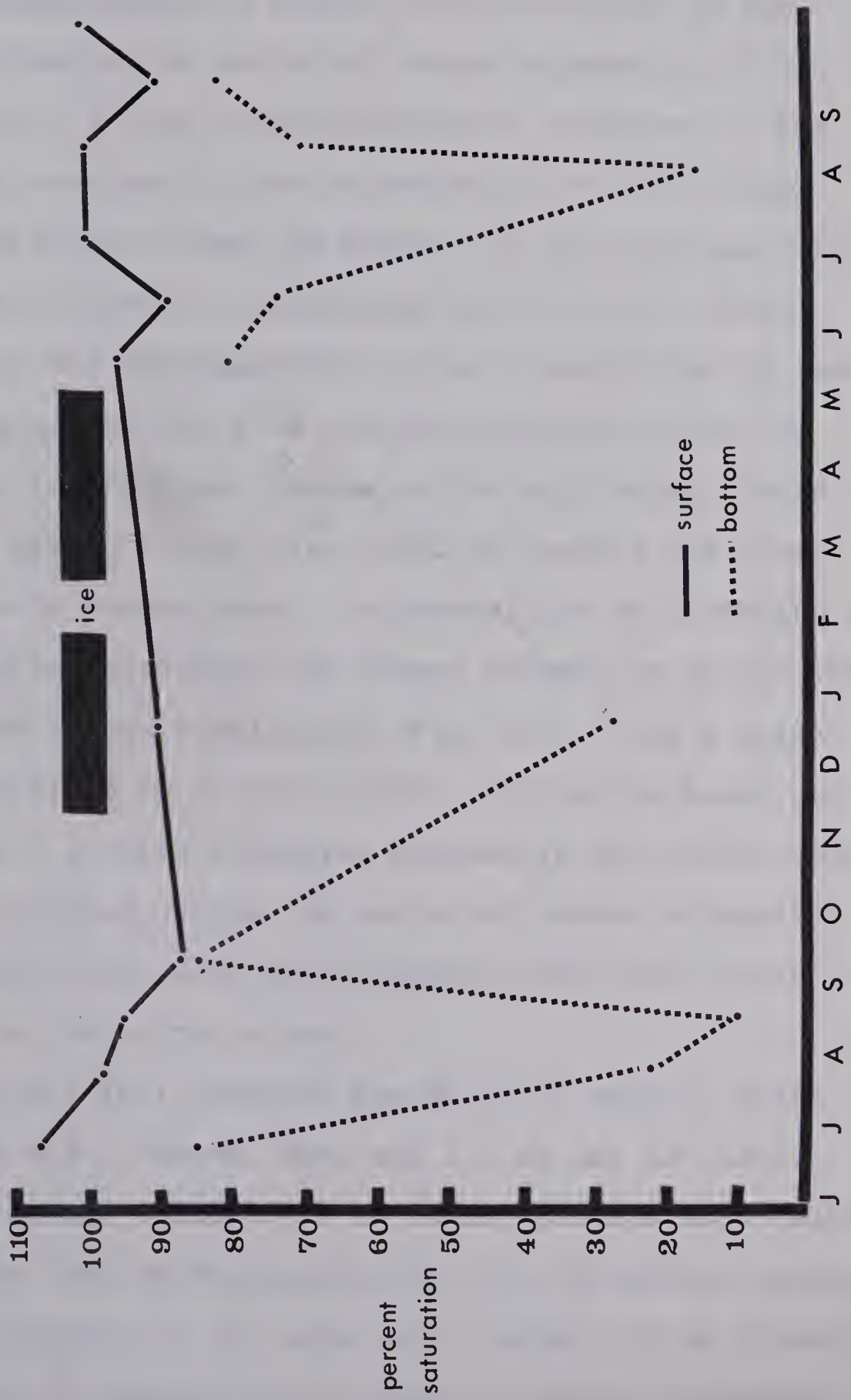


Figure 12. Seasonal cycles of dissolved oxygen in
Lac La Biche from June, 1965 to September,
1966.



2. Hydrogen Ion Concentration

Both Lac La Biche and Beaver Lake are alkaline, with hydrogen ion concentration varying from pH 7.2 to 8.8. The pH of the hypolimnion is always lower than that of the epilimnion during the period of summer stagnation (Figs. 13a and 13b). A lack of photosynthetic organisms in the hypolimnion resulted in the accumulation of free carbon dioxide and hence a lower pH there. In the epilimnion the free carbon dioxide is assimilated by the active photosynthesis of the phytoplankton and as a result the pH increases. While the great majority of the photosynthetic activity takes place in the upper layers of the epilimnion, there is sufficient mixing within this layer to deplete the free carbon dioxide accumulated. In general the pH increased in the epilimnion throughout the summer stagnation period while it decreased in the hypolimnion (Fig. 13). Such a situation is described by Ruttner (1963). In Lac La Biche and Beaver Lake a similar situation existed in the winter under the ice as existed during the period of summer stagnation, which suggests that some photosynthesis does take place under the ice during the winter.

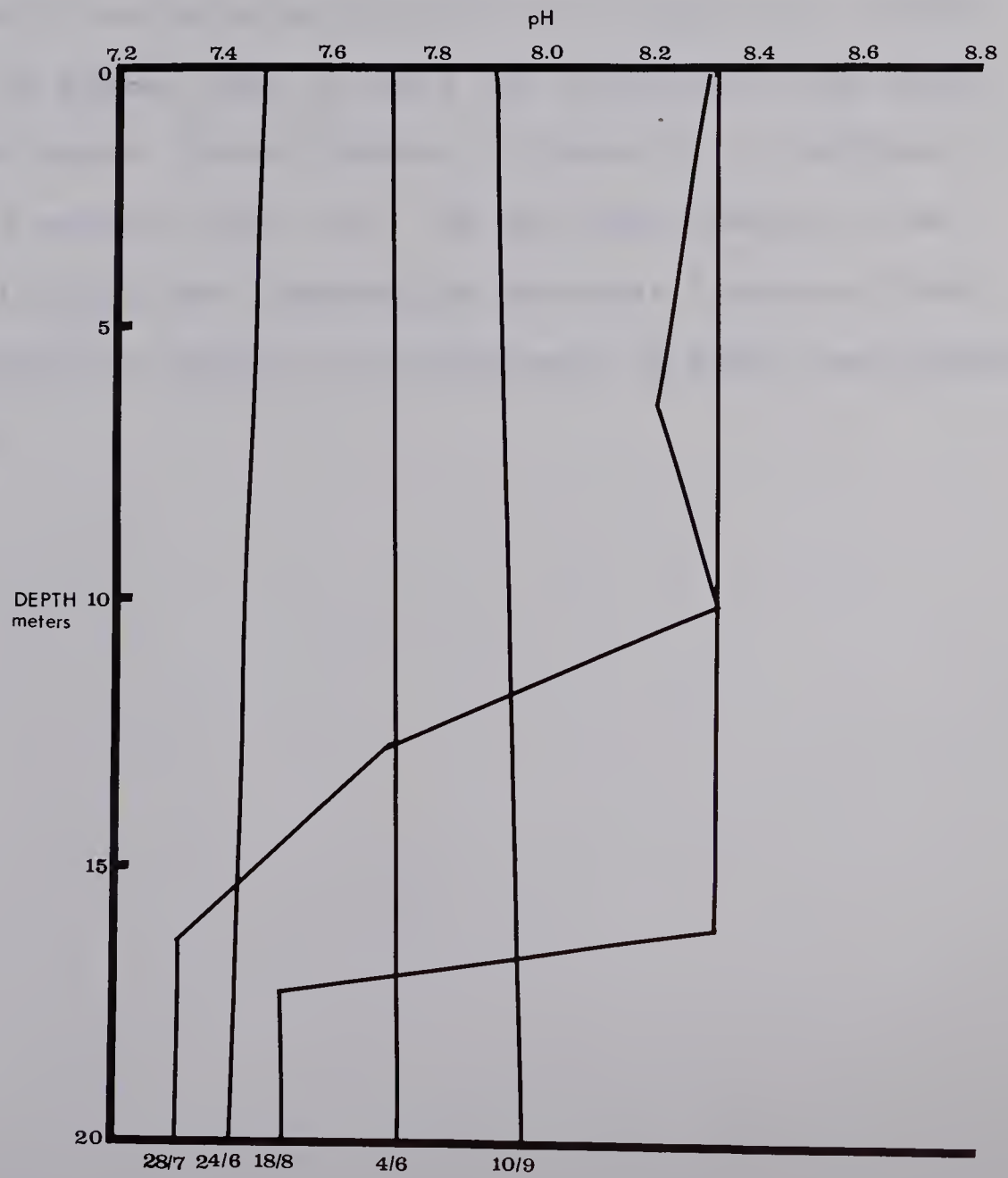
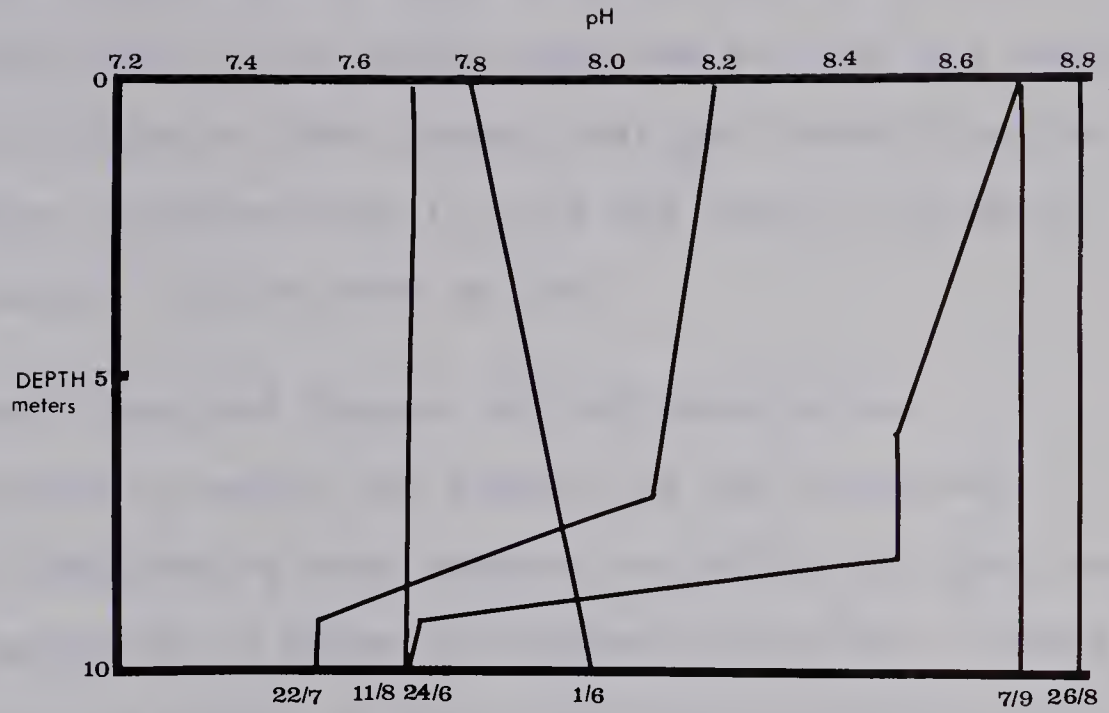
During the fall overturn the pH is in general quite high, about 8.8 in Beaver Lake and 7.9 in Lac La Biche. During the spring turnover it is lower, perhaps as a result of the lower rate of photosynthesis over the winter period.

The situation in the lakes with respect to pH closely mirrors that of temperature in that it clearly delineates the epilimnion, metalimnion, and hypolimnion of the lakes.

Figure 13a. Hydrogen ion concentration in Beaver
Lake, 1965.

Figure 13b. Hydrogen ion concentration in Lac
La Biche, 1965.

date — day/month



Only the 1965 values are recorded in Figure 13 to simplify the graph. The values obtained in 1966 are nearly identical to those of 1965 except that the stratification is of shorter duration than in 1965 and hence the pH in the hypolimnion did not drop as low.

3. Combined Dissolved Oxygen, pH and Temperature

The extent to which the results of pH, dissolved oxygen and temperature data combine to define the position of the metalimnion is shown in Figures 14a to 15b. These data are for the months of July and August of 1965, the time during which the lakes were stratified during the summer period. In Beaver Lake in July the metalimnion was about two meters thick, during August it grew to a thickness of about 4 meters (Fig. 14). On the other hand, in Lac La Biche in July the thermocline was about 6 meters thick, but decreased in August to a thickness of about two meters (Fig. 15).

Figure 14a. Temperature, dissolved oxygen and hydrogen ion concentration in Beaver Lake, July, 1965.

Figure 14b. Temperature, dissolved oxygen and hydrogen ion concentration in Beaver Lake, August, 1965.

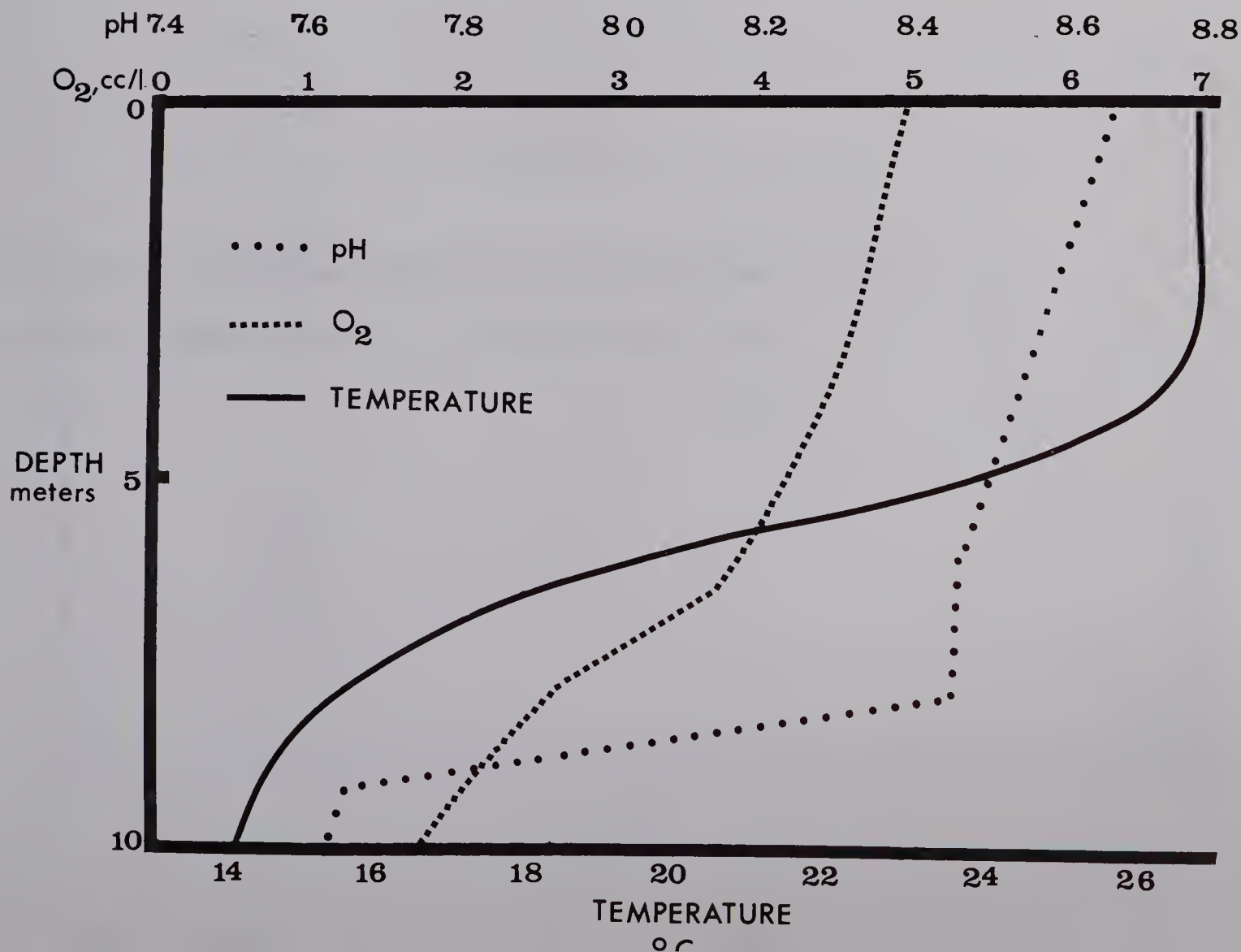
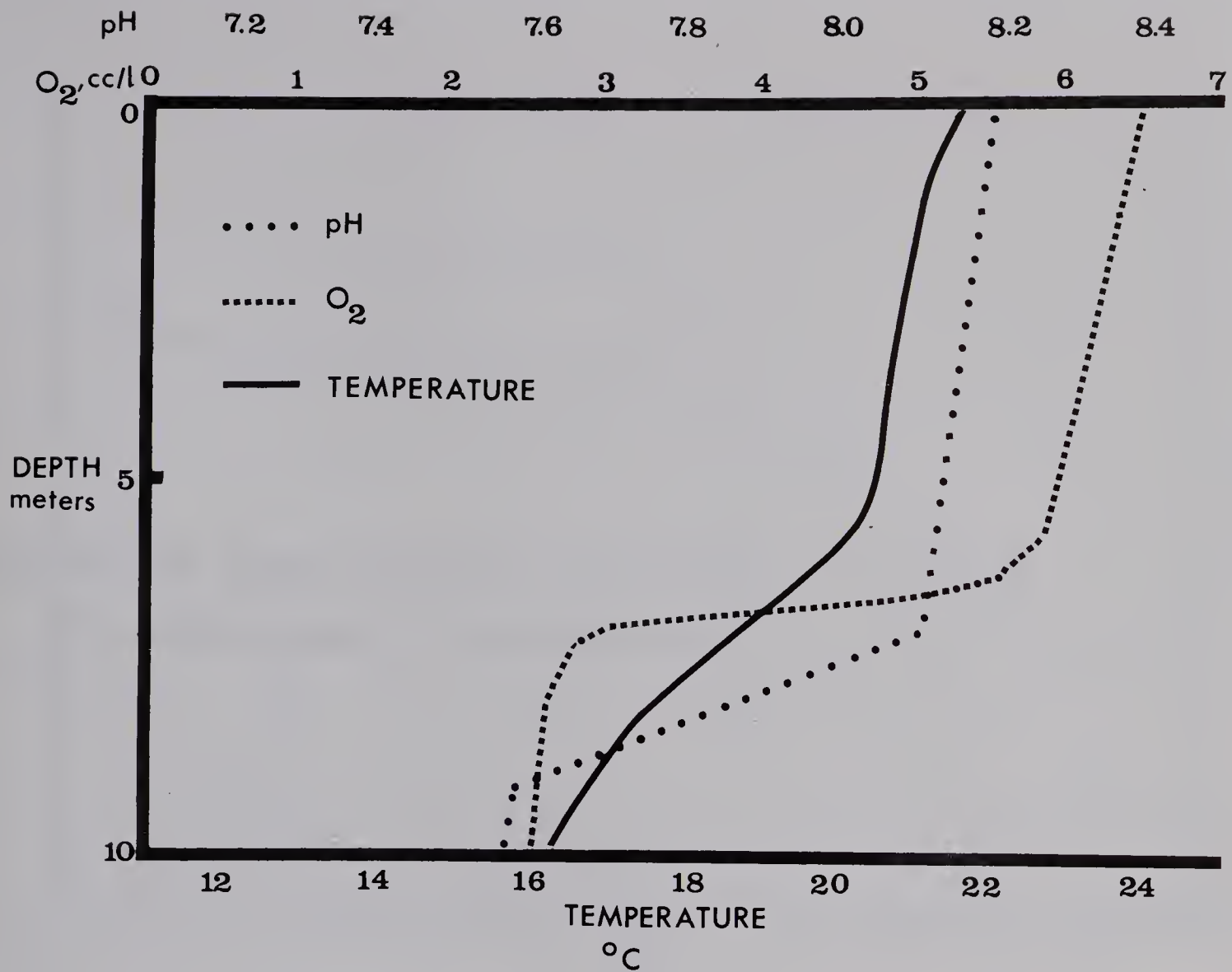
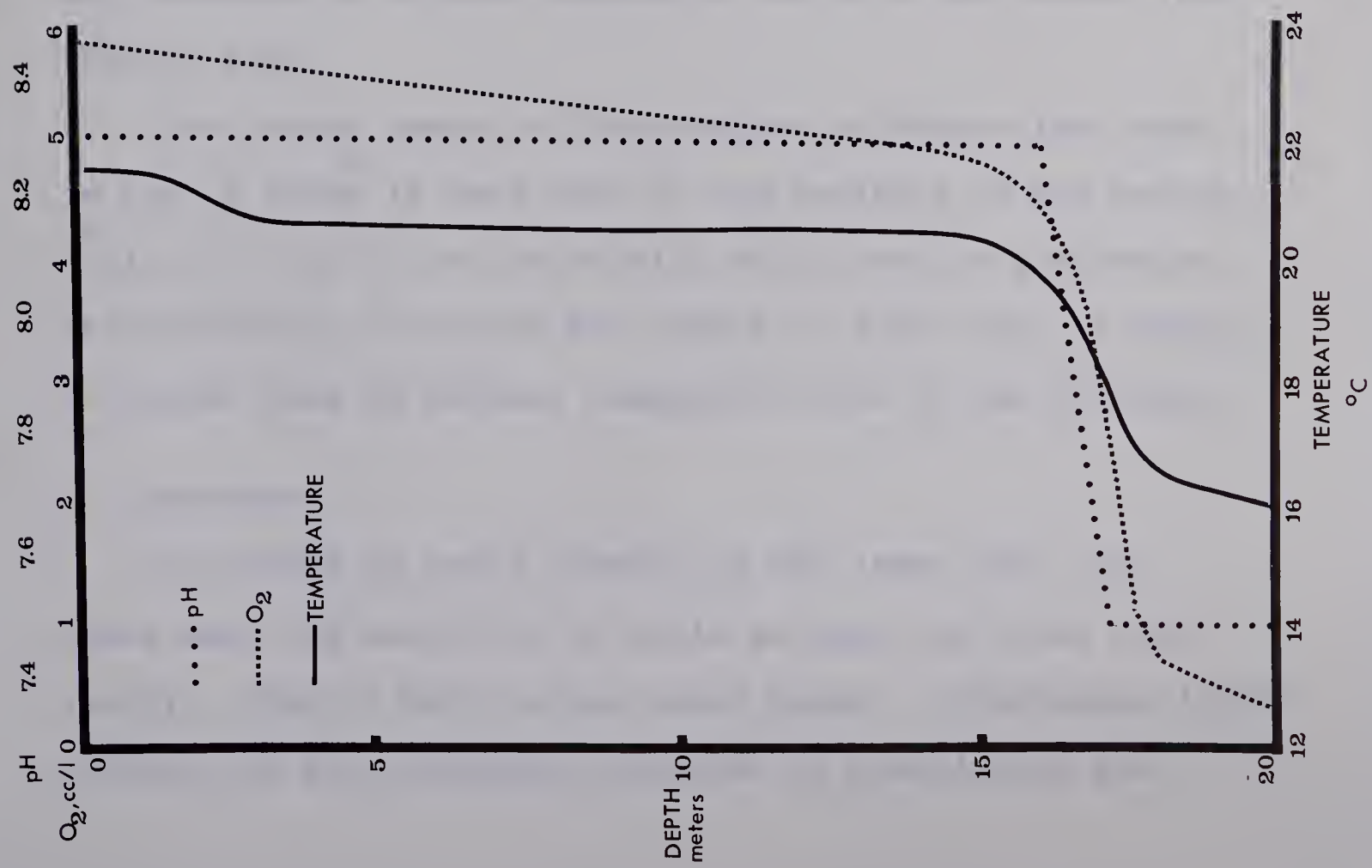
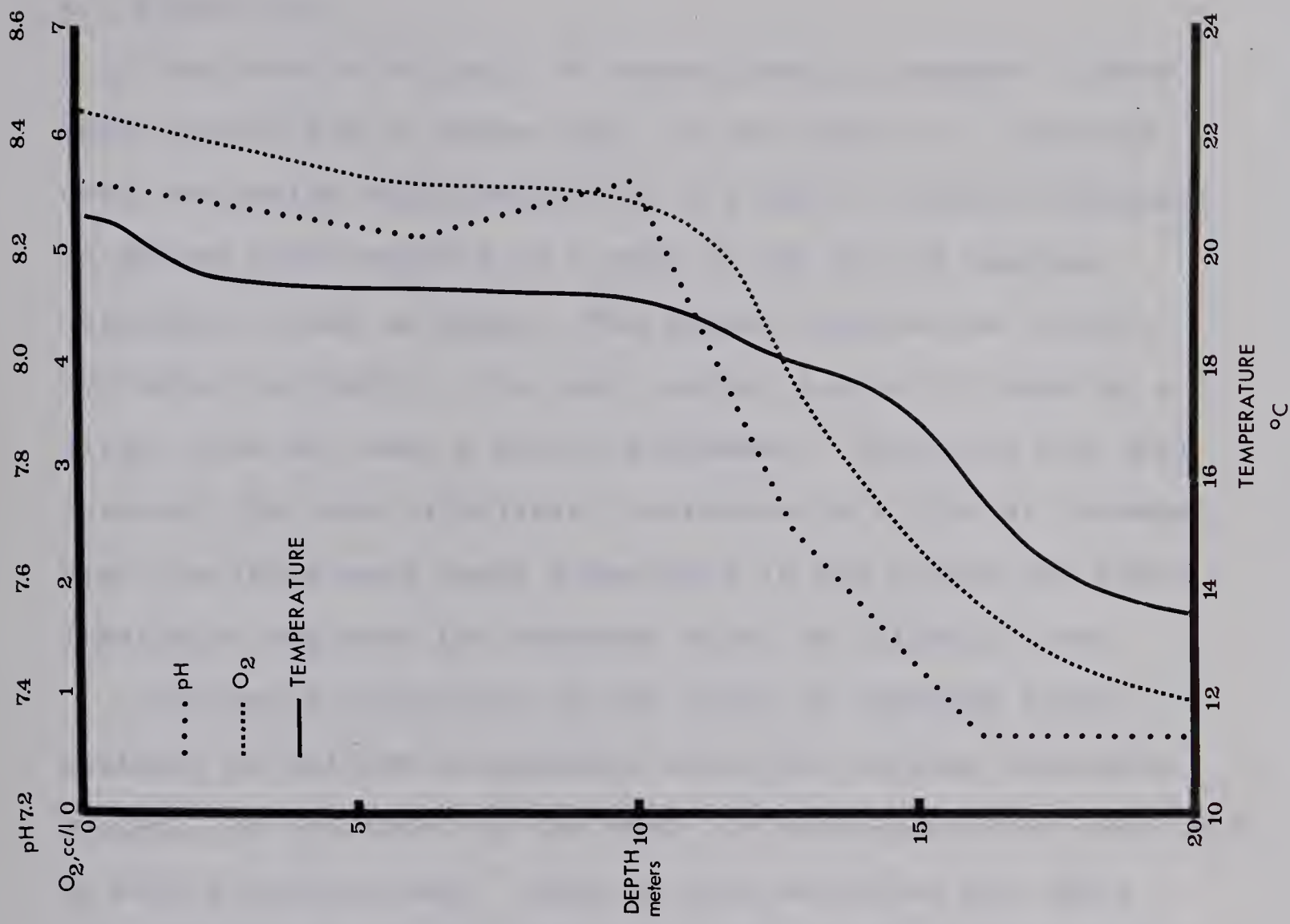


Figure 15a. Temperature, dissolved oxygen and hydrogen ion concentration in Lac La Biche, July, 1965.

Figure 15b. Temperature, dissolved oxygen and hydrogen ion concentration in Lac La Biche, August, 1965.



4. Alkalinity

The total alkalinity of Beaver Lake is somewhat higher than that of Lac La Biche (Fig. 16 and Table V). The mean over the entire study period was 201 ppm of calcium carbonate in Beaver Lake compared to a mean of 141 ppm of calcium carbonate in Lac La Biche. The annual fluctuation in the two lakes is similar. An early spring low is followed by a slight rise and then a dip in midsummer. Following the fall turnover the total alkalinity increases to a high in December. When the lakes were again accessible in the spring the total alkalinity was near the December value or slightly lower.

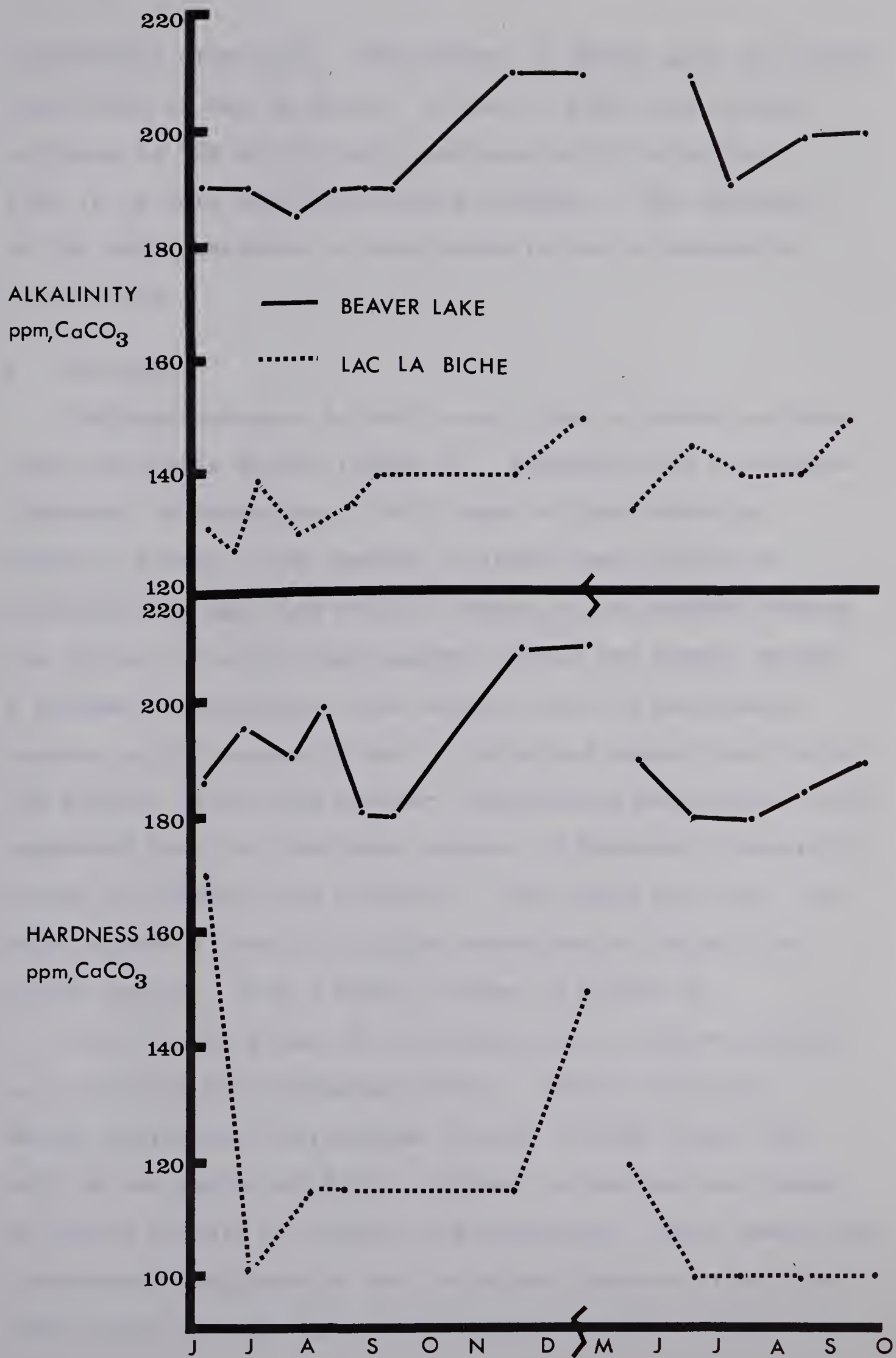
The total alkalinity of the lakes is composed almost entirely of calcium bicarbonate since the calcium carbonate content, as indicated by the test for phenolphthalein alkalinity, is nearly non-existent. Only on rare occasions was there any evidence of calcium carbonate and this was always less than 10 ppm.

The larger amount of bicarbonate in Beaver Lake than in Lac La Biche is seen also in the analysis of the bottom soils, as done by the Provincial Soils Testing Laboratory. The Laboratory evaluated the amount of free lime, $\text{Ca}(\text{HCO}_3)_2$, in Beaver Lake as medium, compared to low in Lac La Biche.

5. Hardness

The graph of total hardness of the lakes (Fig. 16) shows much the same kind of cycle as that for total alkalinity. This is much as one would expect. Hutchinson (1957) pointed out that temporary hardness is practically the

Figure 16. Seasonal changes in alkalinity and hardness.



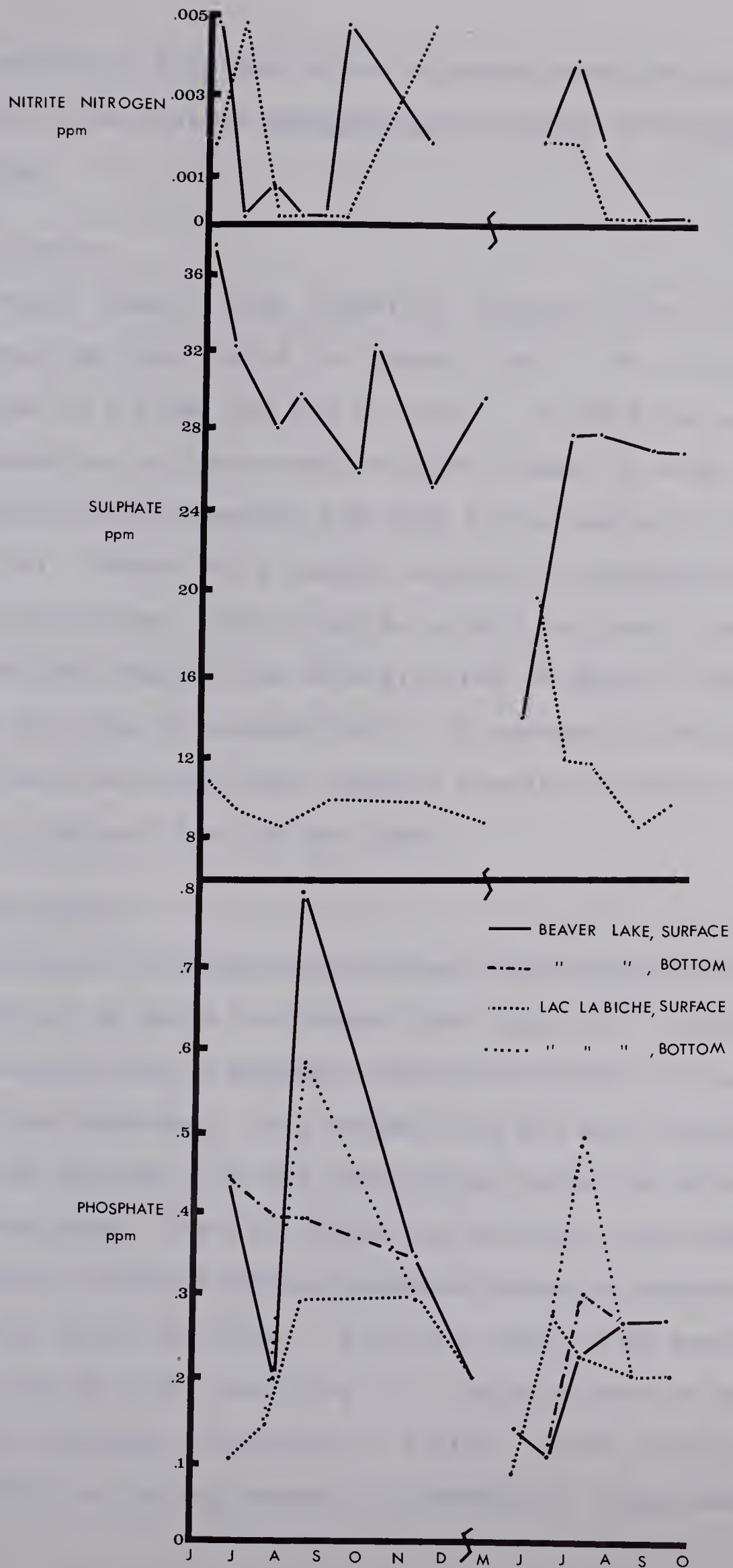
bicarbonate alkalinity. The waters of Beaver Lake are harder than those of Lac La Biche. In Lac La Biche the calcium hardness is 62% of the total hardness while in Beaver Lake it is only 46% of the total hardness. The remainder of the total hardness in both cases is due to magnesium bicarbonate.

6. Nitrogen

Nitrate nitrogen in both lakes shows a marked increase over the winter period (Table V). Domogalla and co-workers (reported in Hutchinson, 1957) found nitrate-reducing bacteria always to be present in lakes they studied in Wisconsin, and that the rate of reduction was minimal during the spring and winter and maximal during the summer period. A similar distribution could account for the increase in nitrate in the waters of Lac La Biche and Beaver Lake during the winter. Klein and Steiner (reported in Hutchinson, 1957) concluded that the resultant product of bacterial denitrification of nitrates was nitrites. This being the case, one might expect a drop in nitrite concentration during the winter period. Such a drop is shown in Figure 17.

Nitrite was found in the lakes only in minute amounts, as is typical of unpolluted waters. Nitrite nitrogen showed spring and fall maxima in 1965 in both lakes, but only in the spring of 1966. Diatoms in cultures are known to reduce nitrate to nitrite and Hutchinson (1957) deems this a reasonable explanation for the minute amounts of nitrite often found in well-oxygenated surface waters. Spring and

Figure 17. Seasonal change in nitrite nitrogen,
sulphates and phosphates.



fall maxima of nitrites in Lac La Biche correlate well with blooms of the diatoms Stephanodiscus astrea and Fragillaria capucina.

7. Sulphates

Beaver Lake is much higher in sulphates than is Lac La Biche. The mean value for Beaver Lake is 29 ppm as compared to 9.2 ppm for Lac La Biche. In 1965 the sulphate concentration followed much the same trends in both lakes. An interesting phenomenon was seen in the spring of 1966 (Fig. 17). There was a marked increase in sulphates in Beaver Lake from a low in May to a high in June. Just the opposite was seen in the data from Lac La Biche. The reason for this is unknown but it is assumed to be something resulting from other than climatic conditions since they are nearly identical for the two lakes.

8. Phosphates

Phosphate concentrations showed much the same trends in both Lac La Biche and Beaver Lake (Fig. 17). In both years of the study a maximum concentration was realized in August and September. The maximum was far more marked in 1965 than in 1966. It was much higher in Lac La Biche than in Beaver Lake. The high value for 1965 may have occurred as a result of the numerous plankton blooms in August, particularly in Lac La Biche. With the onset of the overturn, bloom species died, resulting in a large release of phosphate as these organisms decomposed. Ruttner (1963) mentioned the ability of phytoplankters to accumulate large amounts

of phosphorus, even more than is necessary for the maintenance of the numbers present if an excess is available. There was some stratification of phosphates in the lakes. In most cases there was a higher concentration in the hypolimnion than in the epilimnion. However, during the latter part of the summer of 1965 just the reverse was shown to be the case (Fig. 17).

9. Silica

The lake waters were examined for silica content at irregular intervals during the summer of 1965. Beaver Lake water had about 2.5 ppm of silica while Lac La Biche had a concentration of about 3 ppm. It is expected that these values varied widely, mostly as a result of diatom blooms in the spring and fall.

10. Chloride

Chloride content was determined during the summer of 1966. It was found in both lakes to be highest in July and August, dropping markedly to a value of about 1/100 of that concentration recorded in August in September. In Beaver Lake the chloride content reached a high of 10 ppm in August and in September had fallen to a value of .1 ppm. In Lac La Biche the same trend was seen but to a lesser degree, the high in August being 5.0 ppm, falling to .15 ppm in September.

11. Analysis of Bottom Muds

Table VI gives the bottom mud analysis of Beaver Lake and Lac La Biche. According to the Provincial Soils Testing Laboratory results, there is no detectable nitrogen in the bottom mud. The amount of phosphorus reported is considered low by the Laboratory. The phosphorus content is nearly identical in the two lake muds. Potassium content of Beaver Lake mud is considered medium while that of Lac La Biche is very high. It is interesting to note that there is twice as much potassium in Lac La Biche mud as in Beaver Lake mud. The free lime, bicarbonate, is classed as medium in Beaver Lake and low in Lac La Biche, corresponding to the bicarbonate content of the waters. The pH and conductivity of both bottom muds are nearly the same.

Table V. Chemical Composition of Waters of Beaver Lake
and Lac La Biche.

LAC LA BICHE				
	Summer 1965	Winter	Summer 1966	Mean
Total Alkalinity, ppm CaCO_3	134	147	144	141
Total Hardness, CaCO_3 ppm	116	150	121	129
Calcium Hardness, CaCO_3 ppm	82	80	78	80
Magnesium Hardness, MgCO_3 ppm	34	60	43	46
Nitrate Nitrogen, ppm	.75	1.5	.50	.92
Nitrite Nitrogen, ppm	.0004	.005	.001	.002
Total Sulphate, ppm	8.0	8.5	11.0	9.2
Total Phosphate, ppm	.28	.22	.25	.25

BEAVER LAKE				
	Summer 1965	Winter	Summer 1966	Mean
Total Alkalinity, ppm CaCO_3	192	210	202	201
Total Hardness, CaCO_3 ppm	190	208	190	196
Calcium Hardness, CaCO_3 ppm	91	100	86	92
Magnesium Hardness, MgCO_3 ppm	99	108	104	104
Nitrate Nitrogen, ppm	.32	2.0	.75	1.02
Nitrite Nitrogen, ppm	.002	.002	.001	.001
Total Sulphate, ppm	32.5	29	26	29
Total Phosphate, ppm	.51	.24	.11	.29

Table VI. Analysis of Bottom Muds.

	Beaver Lake	Lac La Biche
Phosphorus	181.5 kg/ha	154 kg/ha
Potassium	1056 kg/ha	1947 kg/ha
Nitrogen	nil	nil
Sulphates	medium	medium
Free Lime	medium	low
pH	7.8	7.5
Conductivity	1.0 mmho	1.6 mmho

VI BIOLOGICAL CHARACTERISTICS

1. Rooted Aquatic Plants

It is surprising that Beaver Lake, which has much less littoral area per unit of shoreline than has Lac La Biche (see hypsographic curves, Figs. 3a and 3b), should have a richer flora of aquatic plants than has Lac La Biche. Twelve species have been recorded from Beaver Lake and only ten from Lac La Biche (Table VII). This perhaps reflects the fact that Beaver Lake has a more varied shoreline than has Lac La Biche. Beaver Lake has shoreline areas of mud, sand, rock and many intergradations. Lac La Biche has extensive areas of sandy or rocky shore. A littoral area which is rocky does not support an extensive flora of rooted aquatic plants. There are also only a limited number of protected backwaters and small bays on Lac La Biche while there are numerous such regions in Beaver Lake. These quiet, protected shallow areas, as shown on the outline maps (Figs. 4 and 5) seem to make a particularly good habitat for aquatic plants. The only forms which seem well adapted to the open wave swept sandy beaches are Potamogeton richardsonii, P. pectinatus and Scirpus validus.

Myriophyllum exalbescens occurred on sandy or slightly muddy bottoms in protected bays or in areas with a Scirpus validus growth further off shore. Polygonum sp. and Sagittaria cuneata as well as Typha latifolia and Lemna trisulca were found predominantly in protected areas with

a shallow muddy bottom. Ranunculus aquatilis was found along protected sandy shores. Elodea canadensis was an inhabitant of sandy or partly muddy shores. The discovery of a few isolated clumps of Acorus calamus at the extreme southern tip of Beaver Lake was interesting as Moss (1964) describes the species as rare in Alberta. This small portion of low swampy lake at the southernmost tip of the lake was the only place the species was found.

Cladophora sp., a filamentous alga, was found during the summer months in both lakes. It occurred in thick mats on the bottom in several littoral areas. Kerekes (1965) stated that he found Cladophora sp. to be antagonistic to other algae in much the same manner that Hasler and Jones (1949) describe higher plants affecting the growth of planktonic algae. I did not find this to be the case during my observations of this alga. Thick growths of it occurred in areas which were in the midst of a bloom of species of blue-green algae in both 1965 and 1966.

The number of species found varied with the diversity of habitats and the relative amount of protected areas available to them in the two lakes.

2. Fish

a. Distribution

Lac La Biche has a richer fish fauna in terms of numbers of species than does Beaver Lake (Table VIII). Eleven species were found in Lac La Biche and eight in Beaver Lake. All of the species occurring in Beaver Lake

Table VII. Occurrence of Aquatic Plants in Beaver Lake
and Lac La Biche.

	Beaver Lake	Lac La Biche
<u>Potamogeton pectinatus</u> L.	x	x
<u>Potamogeton pusillus</u> L.	x	x
<u>Potamogeton richardsonii</u> (Benn.)	x	x
<u>Potamogeton zosteriformes</u> Fern	-	x
<u>Myriophyllum exalbescens</u> L.	x	x
<u>Typha latifolia</u> L.	x	x
<u>Sagittaria cuneata</u> Sheld.	x	-
<u>Scirpus validus</u> Vahl.	x	x
<u>Elodea canadensis</u> Michx.	x	x
<u>Lemna trisulca</u> L.	x	x
<u>Acorus calamus</u> L.	x	-
<u>Polygonum</u> sp.	x	-
Number of species	12	10

Table VIII. Species of Fish Occurring in Beaver Lake
and Lac La Biche.

	Beaver Lake	Lac La Biche
<u>Coregonus clupeaformis</u> (Mitchill)	x	x
<u>Leucichthys</u> sp.	-	x
<u>Notropis hudsonius</u> (Clinton)	x	x
<u>Esox lucius</u> Linnaeus	x	x
<u>Catostomus catostomus</u> (Forster)	-	x
<u>Catostomus commersoni</u> (Lacepede)	x	x
<u>Lota lota</u> (Linnaeus)	x	x
<u>Etheostoma exile</u> (Girard)	x	x
<u>Stizostedion vitreum</u> (Mitchill)	x	x
<u>Perca fluviatilis</u> Linnaeus	x	x
<u>Culaea inconstans</u> (Kirtland)	-	x

were found in Lac La Biche. Leucichthys sp. (tullibee), Catostomus catostomus (longnose suckers), and Culaea inconstans, (brook sticklebacks), were found only in Lac La Biche. Why these fish do not occur in Beaver Lake is unknown. All three species occur in lakes and streams which are in the Churchill Drainage. During the course of the study Touchwood Lake and Amisk Lake, both in the Beaver River drainage, were investigated and found to contain tullibee. Rawson (1960b) reported both brook sticklebacks and long-nose suckers in lakes he studied in the Churchill drainage in Saskatchewan. The reason for these species of fishes not occurring in Beaver Lake is due to something other than lack of accessibility.

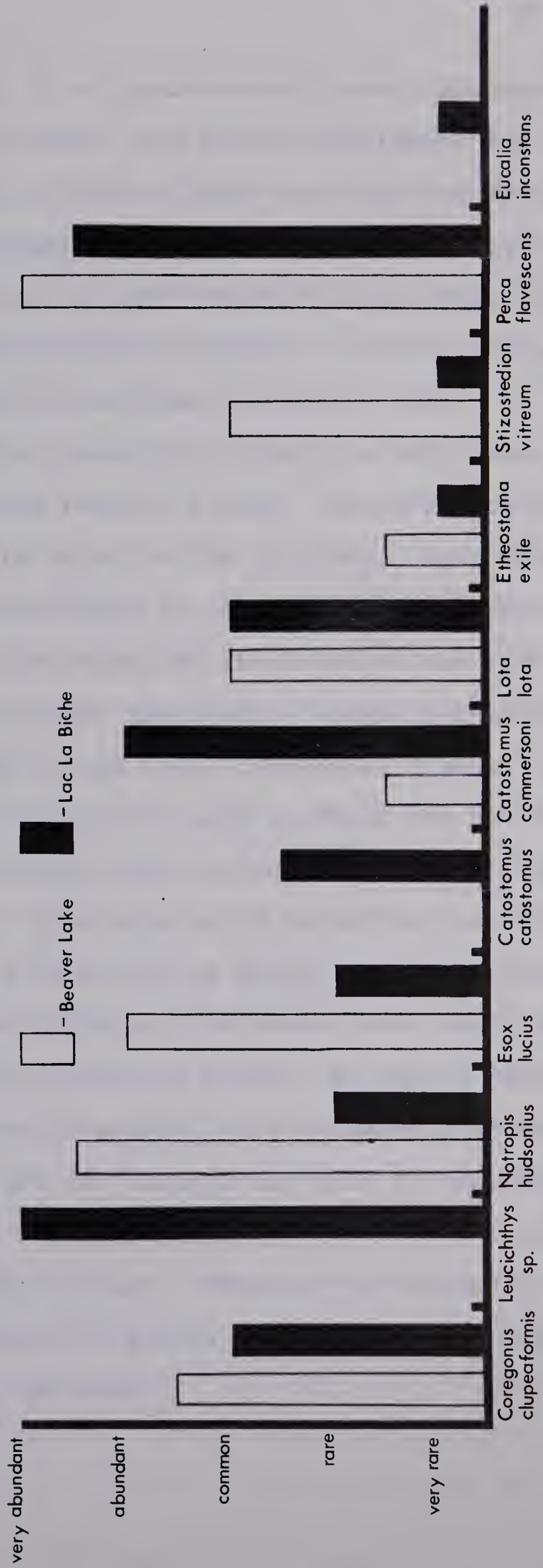
b. Abundance

Although the species composition of the fish populations of these two lakes is similar, the abundance of species varies between the lakes (Fig. 18). This figure is of a semi-quantitative nature and is based on relative abundances as determined from commercial fishery catch records, examination of commercial fishermen's catches and observations of the fish fauna of both lakes.

Lake whitefish (Coregonus clupeaformis), spot-tail shiners (Notropis hudsonius), pike (Esox lucius), walleye (Stizostedion vitreum), and yellow perch (Perca fluviatilis) are the dominant species in Beaver Lake. Tullibee (Leucichthys sp.), lake whitefish; longnose suckers (Catostomus catostomus) and yellow perch are the dominant forms in Lac La Biche.

Figure 18. Relative abundance of fishes in Beaver Lake and Lac La Biche.

(Perca flavescens has recently synonymized with P. fluviatilis)



The burbot (Lota lota) is of approximately equal abundance per unit area in both lakes. The brook stickleback was found only three times in Lac La Biche and only two specimens of the Iowa darter (Etheostoma exile) were found in this lake. It is interesting to note the very large population of the limnetic planktonivorous tullibee in Lac La Biche, which has no ecological counterpart in Beaver Lake.

There is an active commercial fishery on both lakes, though Lac La Biche is far more heavily fished. The most sought after species in Lac La Biche is the tullibee. Both this and its abundance is reflected in the results in Appendix C. It must be noted that both the abundance of the fish and the fishing intensity affect the results shown in this table. Tullibee make up 66.8% of the total commercial fishery in poundage. Whitefish account for only 11.8% of the total catch on Lac La Biche while they account for 57.9% of the catch in Beaver Lake. Pike make up 19.2% of the catch in Beaver Lake and only 5.2% in Lac La Biche. Walleye account for 10.3% of the total poundage from Beaver Lake and 2.2% of the total poundage from Lac La Biche. As can be seen from Appendix C, there seems in general to be a decreasing number of pounds of fish caught per license but this is dependent upon such a number of non-biological variables that it is beyond the scope of this thesis. There is an increasing interest in sport fishery on Beaver Lake. There is very little angling on Lac La Biche.

c. Movements

Many of the species existing in the lakes seemed to exhibit interesting seasonal movements, particularly in relation to spawning. Lake whitefish, which normally occupy a region close to the bottom in the profundal regions of both lakes, begin to move toward littoral areas in late August and early September. They spawn just before the lake becomes ice-covered in late October and early November. Young lake whitefish, of age classes I, (scales with one annulus) and II (scales with two annuli) were caught during mid-summer in the upper reaches of the epilimnion, presumably feeding on plankton. Walleye spawn on gravelly areas in the lake, as is usually the case in Lac La Biche (pers. comm., B. Bidgood, Edmonton, 1967) or may leave the lake and move into one of the outlets in the very early spring, often before the ice is out of the lake, as is the case in Beaver Lake. Rawson (1947) describes much the same situation with regard to walleye in Lac La Ronge, Saskatchewan.

On May 20, 1966, fifteen pike and one walleye were taken by gill net in water ten meters deep in Beaver Lake. It is uncommon to find these species in water this depth at other times of the year. On this date some of the pike had spawned. The walleye had spawned.

Perch are commonly found in Beaver Lake only in the littoral regions of the lake but in Lac La Biche are found throughout the Little Lake. These and many other interesting fish movement problems were not pursued but further work in this area would result in some interesting discoveries.

d. Feeding

The tullibee was the only species found during the study that is a limnetic planktonivore, even during its adult life. Other fish are planktonivorous, at least for short periods during their life. Although no walleye fry were captured, Houde (1967) indicated that young pelagic walleye in lakes exist for the first six weeks of their lives on zooplankton and select copepods actively.

A limited number of stomachs of spot-tail shiners, (Notropis hudsonius) were examined and it was found that this species fed on small littoral bottom fauna; oligochaetes, chironomids and Hyalella azteca in both lakes. There was some littoral zooplankton in these stomachs but only a very small amount in comparison to the whole of the stomach contents.

Many of the fishes in these two lakes depend upon the bottom fauna as a food source. The Iowa darter feeds mostly on insects, amphipods and some ostracods in Beaver Lake. The yellow perch in both lakes feed on insects, particularly Diptera, but seem to be preferentially piscivorous. The suckers can be assumed to be bottom feeders from the form and position of their mouths. The stomach contents of some were investigated but no identifiable remains were found. Kussat (1966) found the same difficulty in trying to identify the stomach contents of the same two species of suckers. However, he was able to identify some Chironomidae and Hemiptera.

The lake whitefish are the only inhabitants of the two lakes which feed to a large extent on the profundal bottom fauna. Some young whitefish were captured in both lakes during the summer in gill nets set near the surface. This would indicate they are feeding on limnetic plankton. Adult lake whitefish feed at all depths on Chironomidae and Pisidium sp. There is some indication that they feed preferentially on Pisidium when available.

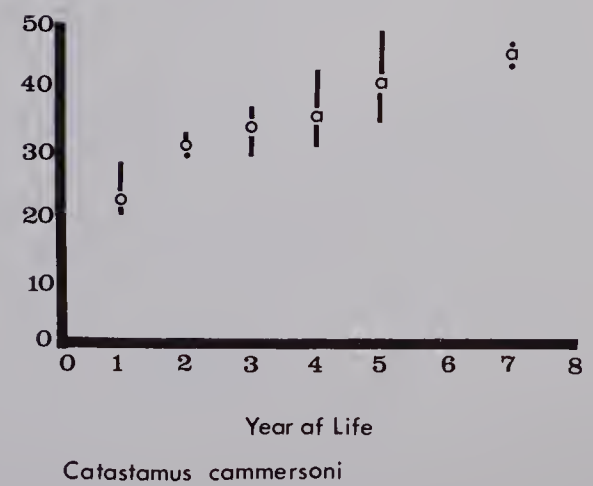
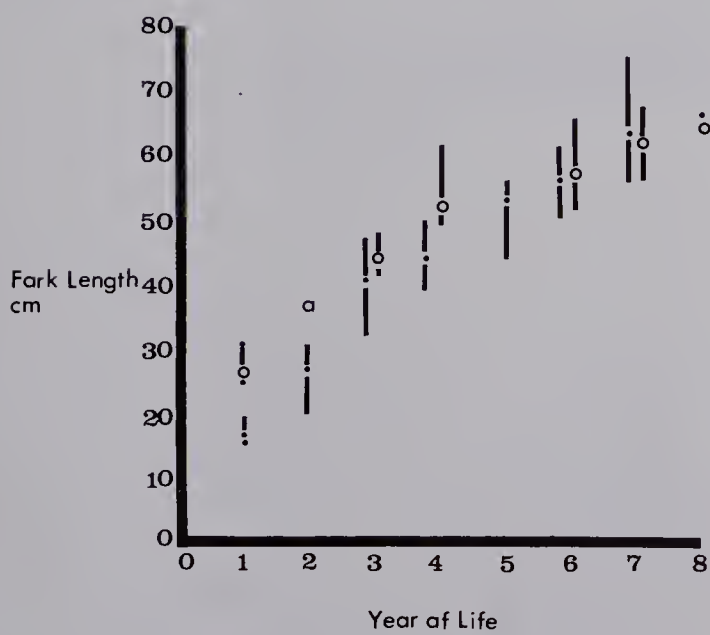
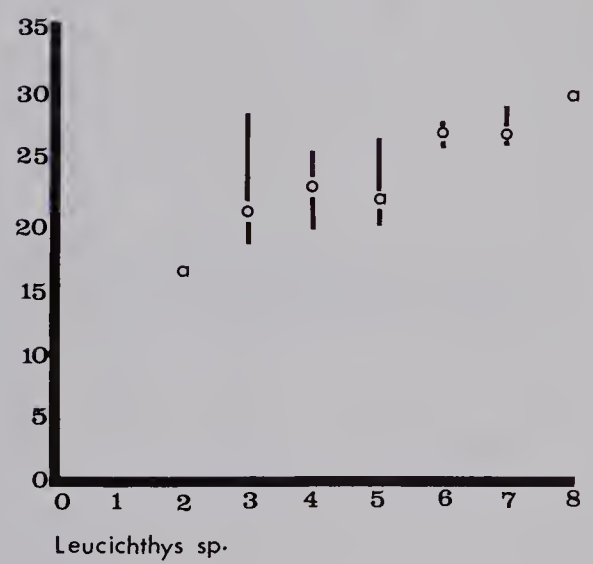
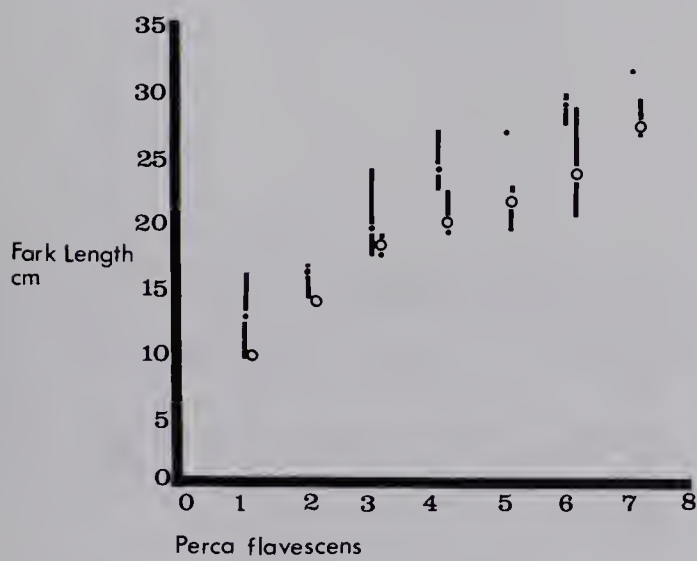
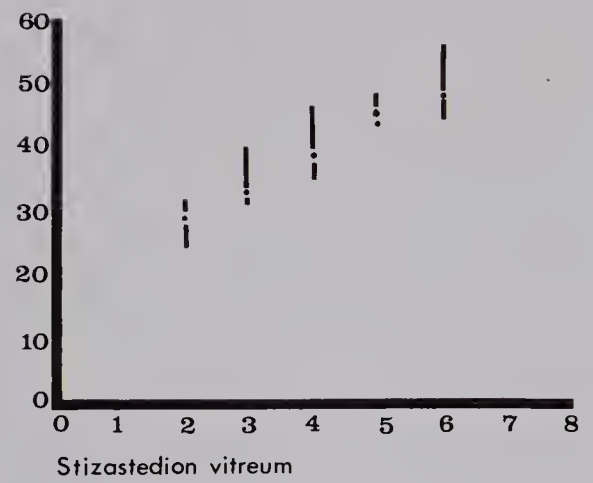
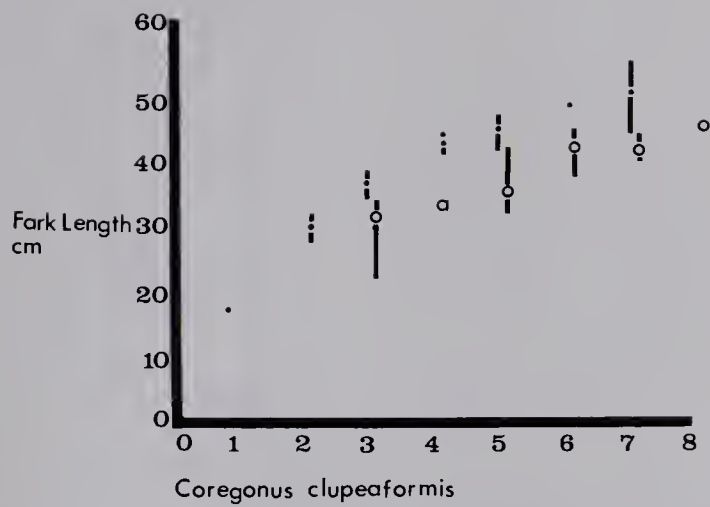
Both the burbot and the northern pike seem to be piscivores from very early stages of their life histories. Pike of 10 cm fork length were found to contain remains of fishes. Adult walleye are piscivorous.

e. Growth

Growth curves for several of the species obtainable by gill nets were constructed (Figs. 19 to 21). Growth curves of lake whitefish, yellow perch and pike were made for each lake and compared (Figs. 19 and 20). These species were chosen for a number of reasons: they were able to be captured in large enough numbers to construct a graph, they occurred in both lakes and they represent food niches common to the fishes of both lakes, a profundal bottom feeder, a littoral bottom feeder and partial piscivore and a littoral piscivore. Both lake whitefish and yellow perch grow faster in Beaver Lake than in Lac La Biche (Figs. 19 and 20). This is the case when one compares length or weight to age. With pike the distinction is not so clear when comparing length to age but when comparing weight to

Figure 19. Relationship between fork length and year of life of six species of fishes from Beaver Lake and Lac La Biche. Vertical lines represent range of sizes.

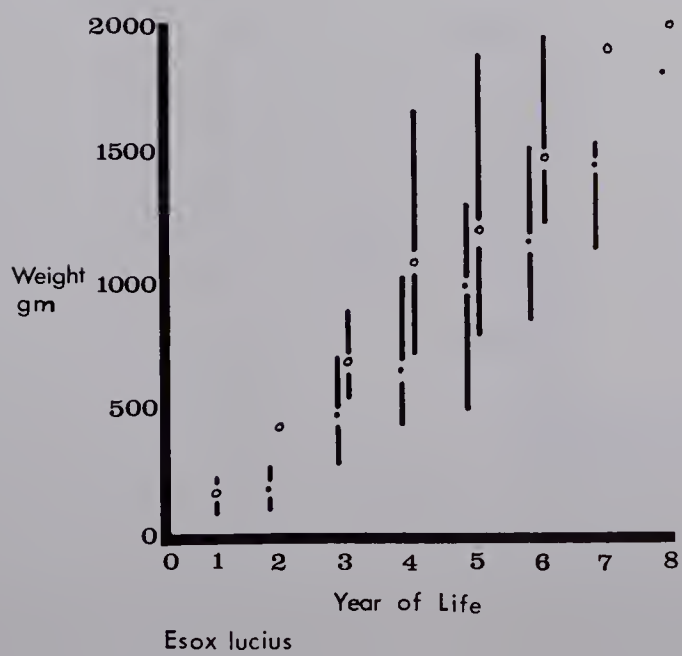
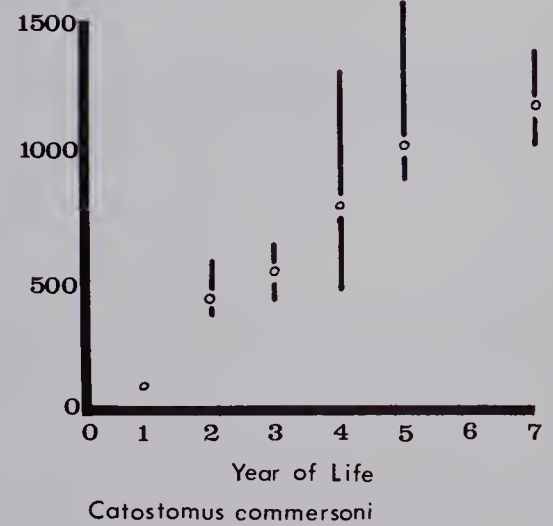
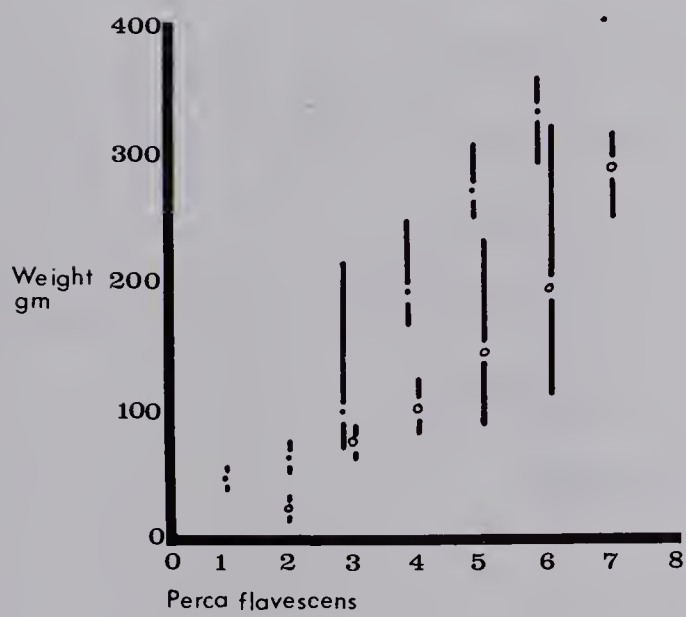
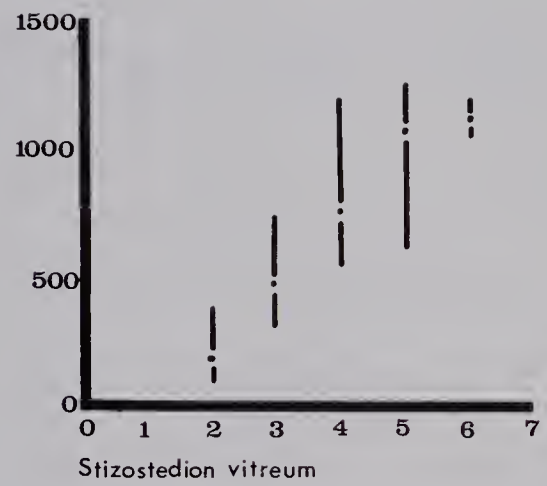
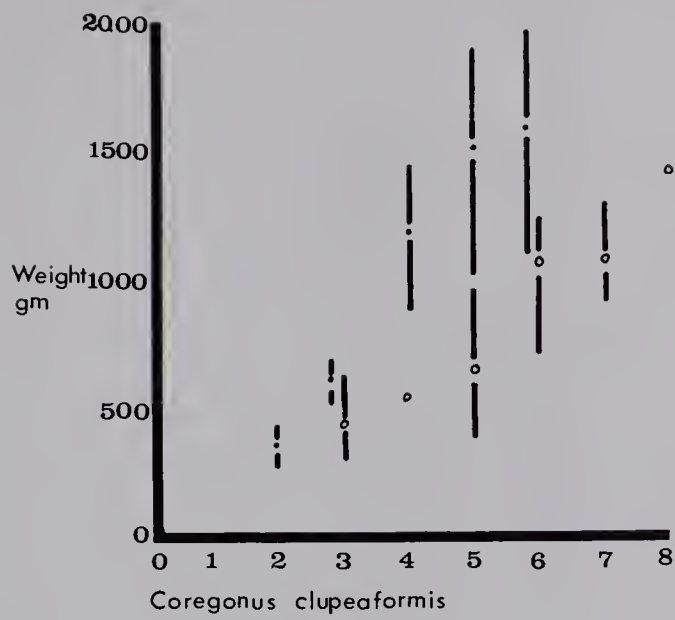
(Perca flavescens has recently synonymized with P. fluviatilis)



α-Lac La Biche
•-Beaver Lake

Figure 20. Relationship between weight and year of life of five species of fishes from Beaver Lake and Lac La Biche. Vertical lines represent range of sizes.

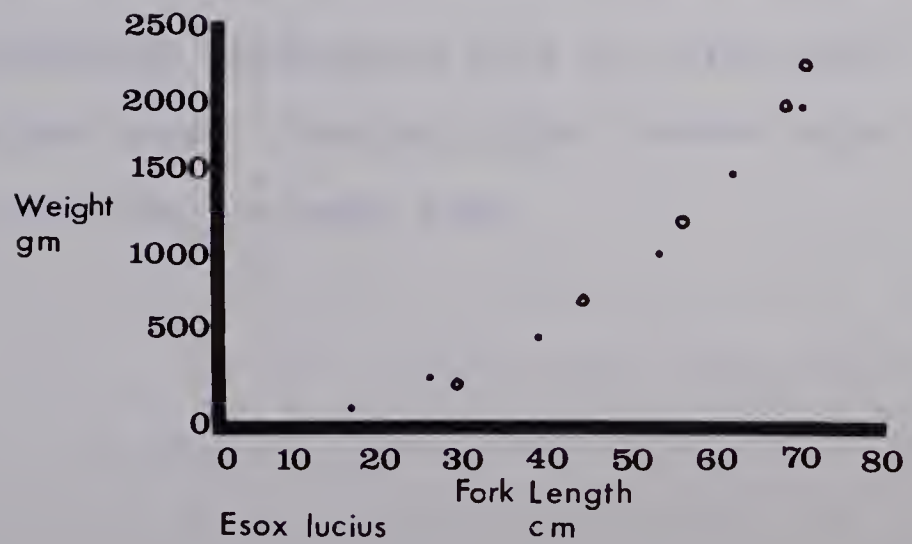
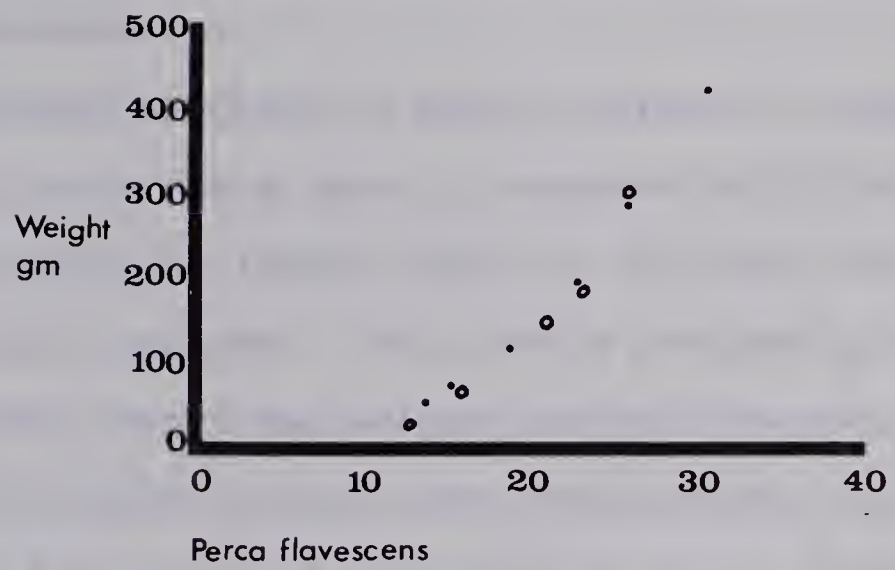
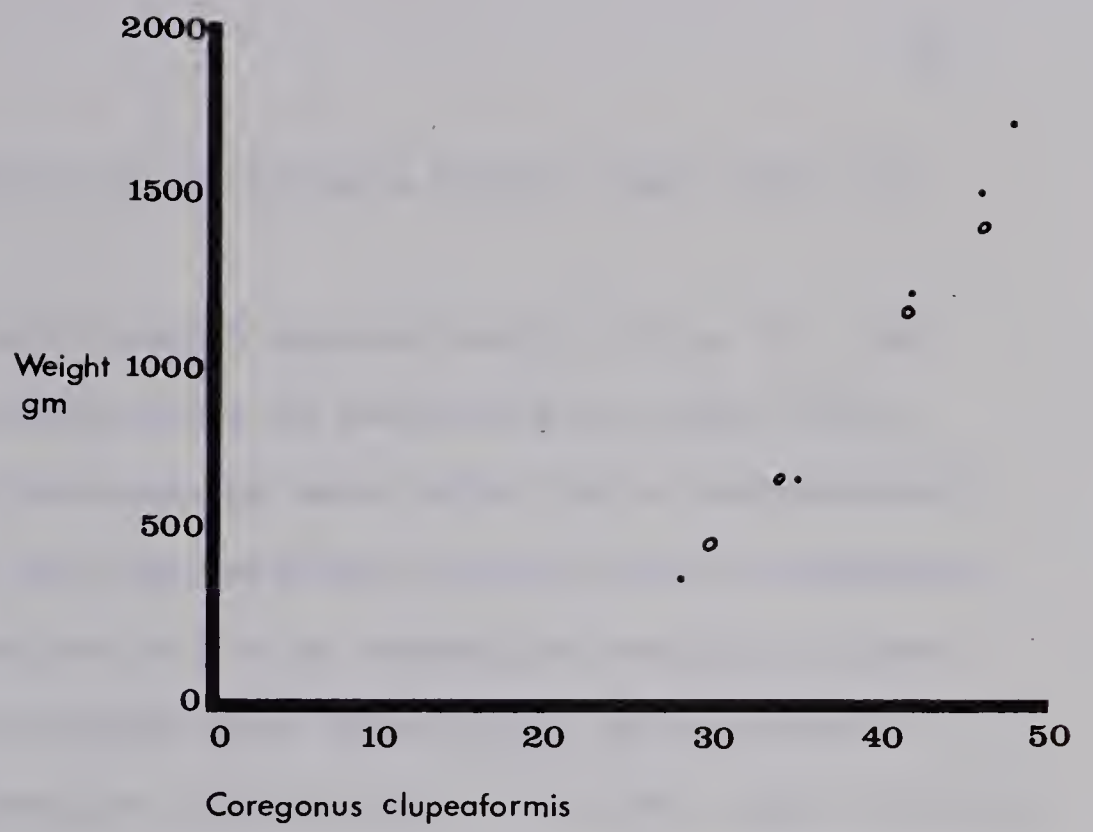
(Perca flavescens has recently synonymized with P. fluviatilis)



○ - Lac La Biche
 ● - Beaver Lake

Figure 21. Relationship between weight and fork length of three species of fishes from Beaver Lake and Lac La Biche.

(Perca flavescens has recently synonymized with P. fluviatilis)



○ - Lac La Biche

• - Beaver Lake

age the pike of Lac La Biche grow faster than those of Beaver Lake.

When one plots length against weight (Fig. 21) the curves for the populations of each lake are very close together, often overlapping each other quite considerably. Since these are the two variables taken into consideration in the determination of a K or condition factor, it does not seem from the graph that there would be any marked difference between the populations of the two lakes in this respect. Since this was shown by the above mentioned graphs, the arduous chore of calculating a K factor for each fish was not undertaken.

All fish studied exhibited a rapid increase in length during the early years while gaining comparatively little weight. When increase in length began to fall off, the rate of weight gain increased. This would presumably be the case to a given length and weight for each species at which time the weight gain per year would become very small. This would result in a sigmoid curve when plotting weight against year of life. This is not shown in any of the species studied with the exception of the walleye of Beaver Lake, presumably because no very old fish were captured during the study. Lagler (1956) showed this form of curve to be the case for most fish.

3. Bottom Fauna

a. Qualitative

i. Littoral

The littoral areas of the lakes exhibit diverse habitats and hence were quite rich in taxa. In this study animals living on or around rooted aquatic plants are included in bottom fauna. Forms such as Gammarus lacustris and the ostracod, Cyclocypris serena, which spend a large part of their lifetime in the waters just above the bottom and on plant material, are also considered in this category.

There seems to be several taxa that occur in only one of the lakes (Table IX). In some cases, for example Hydra sp., the animals were rare in Lac La Biche and did not occur in Beaver Lake. They were not searched for intensively using methods specifically used for collection of this group, such as those described by Paetkau (1964). It is entirely possible that the same taxon does occur in Beaver Lake.

Dugesia sp. was not suitably preserved for species identification. That form found in Lac La Biche seemed to be most abundant on and under rocks on exposed waveswept beaches, while in Beaver Lake, Dugesia sp. was found on rooted aquatic plants and filamentous algae. Stylaria lacustris was the most prevalent oligochaete in the littoral areas of both lakes. The two leeches that were found only in Beaver Lake, Placobdella ornata and Nephalopsis obscura, were represented by only one specimen of each.

Table IX. Bottom Organisms Occurring in Littoral Areas.

	Beaver Lake	Lac La Biche
Coelenterata		
<u>Hydra</u> sp.		x
Platyhelminthes		
Rhabdocoela	x	x
Tricladida		
<u>Dugesia</u> sp.	x	x
Aschelminthes		
Nematomorpha		
<u>Gordius</u> sp.	x	x
Annelida		
Oligochaeta		
<u>Stylaria lacustris</u> (Linnaeus)	x	x
<u>Chaetogaster diaphanus</u>		
(Gruithursen)		x
<u>Nais variabilis</u> Riguet		x
Hirudinea		
<u>Glossophonia complanata</u>		
(Linnaeus)	x	x
<u>Erpobdella punctata</u> (Leidy)	x	x
<u>Placobdella ornata</u> (Verrill)	x	
<u>Nephalopsis obscura</u> Verrill	x	
Mollusca		
Gastropoda		
<u>Physa heterostropha</u> (Say)	x	x
<u>Valvata bicarinata</u> Lea		x
<u>V. tricarinata</u> Say	x	x
<u>V. lewisii</u> Currier	x	x
<u>V. sincera</u> Say		x
<u>Limnaea stagnalis</u> Linne	x	x
<u>L. haldemeri</u> Binney	x	
<u>L. columella</u> Say	x	x
<u>L. palustris</u> Müller		x
<u>Heliosoma trivolvis</u> (Say)	x	x
<u>Heliosoma camplanatum</u> (Say)	x	x
<u>Gyraulus parvus</u> Say		x
<u>G. crista</u> Linne		x
Pelecypoda		
<u>Sphaerium</u> sp.	x	x
<u>Pisidium</u> sp.	x	x

continued

Table IX. Continued.

	Beaver Lake	Lac La Biche
Arthropoda		
Ostracoda		
<u>Cyclocypris serena</u> (Koch)	x	x
<u>C. laevis</u> (Meuller)	x	
<u>Potamocypris</u> sp.		x
<u>Limnocythere herricki</u> Straplin		x
Amphipoda		
<u>Gammarus lacustris</u> Sars	x	x
<u>Hyalella azteca</u> (Saussure)	x	x
Arachnida		
Acari	x	x
Insecta		
Odonata		
<u>Enallagma</u> sp.	x	
Ephemeroptera		
<u>Baetis</u> sp.	x	x
<u>Callibaetis</u> sp.		x
<u>Leptophlebia</u> sp.	x	x
<u>Caenis</u> sp.		x
<u>Stenonema</u> sp.		x
Trichoptera		
<u>Oecetis</u> spp.	x	x
<u>Helicopsyche</u> sp.		x
<u>Banksiola</u> sp. or		
<u>Agrypnia</u> sp.	x	
Coleoptera		
Hydrophilidae	x	x
<u>Anchytarsus</u> sp.		x
<u>Anchycteis</u> sp.	x	x
Hemiptera		
Corixidae	x	x
Diptera		
Chironomidae	x	x
Culicidae		x
Tabanidae		x

Gyraulus crista is a rare species in Alberta. It was found in a shallow enclosed bay in Lac La Biche, which had a very heavy growth of rooted aquatic plants. It is quite possible this species occurs only in Lac La Biche, since there is no area that presents a similar habitat in Beaver Lake.

The ephemeropteran Callibaetis sp. was represented by one cast nymphal exoskeleton found in the water beside the Department of Transport dock in the town of Lac La Biche. Stenonema sp., another ephemeropteran, is a very small species closely attached to rocks on exposed beaches in Lac La Biche.

The trichopteran genus Oecetis was represented by at least three species in Lac La Biche and two in Beaver Lake. Helicopsyche sp., a caddis fly with a very characteristic snail shell-like case, was found only in Lac La Biche.

Thirty-two taxa representing five phyla were found in the littoral area of Beaver Lake, while forty-three taxa, representing six phyla were found in the littoral areas of Lac La Biche.

ii. Profundal

The most striking feature of the profundal bottom fauna is its paucity (Table X). This is due at least in part to the uniformity of the bottom in the profundal areas. The bottom sediment is made up almost exclusively of gyttja in the profundal areas of both lakes. This paucity of forms may also be due in part to the sampling method used. An

Table X. Bottom Organisms Occurring in Profundal Areas.

	Beaver Lake	Lac La Biche
Annelida		
Oligochaeta		
Lumbriculidae	x	x
<u>Limnodrilus</u> sp.	x	x
<u>Limnodrilus hoffmeisteri</u>		
(Claparede)	x	x
<u>Ilyodrilus templetoni</u> Eisen	x	x
<u>Stylaria lacustris</u> (Linnaeus)	x	x
<u>Chaetogaster diaphanus</u>		
(Gruithuisen)		x
Mollusca		
Pelecypoda		
<u>Pisidium</u> sp.	x	x
<u>Sphaerium</u> sp.	x	x
Arthropoda		
Amphipoda		
<u>Gammarus lacustris</u> Sars	x	x
Insecta		
Trichoptera		
<u>Oecetis</u> sp.		
<u>Caenis</u> sp.		
<u>Banksiola</u> sp. or		
<u>Agrypnia</u> sp.	x	
Diptera		
Chironomidae	x	x
Deuterophlebiae	x	x
Ceratopogonidae	x	x
Culicidae		
<u>Chaoborus</u> sp.	x	x

Ekman dredge was the only means available for sampling this area.

The oligochaetes Stylaria lacustris and Chaetogaster diaphanus occurred in the littoral areas of the lakes and were found in the profundal areas of Lac La Biche only. This may be due to the Little Lake portion of Lac La Biche never stratifying, hence making this benthic area similar to the littoral areas and allowing colonization by the two forms.

Pisidium sp. and Sphaerium sp. occur in moderate numbers in the profundal areas of both lakes. The trichopterans listed in Table X are found only rarely in the bottom samples from profundal areas. Members of the family Chironomidae are the most abundant organisms in the profundal areas of both lakes. Chaoborus sp. is found only rarely in both lakes and is in general found in samples which were taken over a rocky or sandy bottom.

b. Quantitative

The standing crop in both lakes during the summer periods is quite variable (Fig. 22). The low value for Beaver Lake in 1966 may be due to the lower percentage of Chironomidae making up the total biomass (Fig. 23). The mean value for dry weight biomass in kilograms per hectare for the two years of the study is 14.30 for Beaver Lake and 79.61 for Lac La Biche. Rawson (1953) suggested the formula:

$$f = \frac{69.2}{(d-5)0.778}$$

for calculating standing crops of bottom fauna from mean depth. The symbol f is the standing crop in kg per ha in dry weight and d is the depth in meters. The constant 69.2 and exponent 0.778 were derived from a curve based on measurements from a number of large lakes in Canada. This formula gives a value of 41.7 kg/ha for Beaver Lake and 34.7 kg/ha for Lac La Biche. As can be seen by comparison with Table XI, Beaver Lake is far below this value and Lac La Biche has a mean standing crop of more than twice this calculated value. Rawson pointed out that the formula was computed from an analysis of large lakes in Canada and as such fails to take into account the many other factors influencing the standing crop of bottom fauna in smaller lakes. By his standards of large and small Lac La Biche is in the large class while Beaver Lake would be considered small. One would think the general rule of smaller mean depth resulting in greater production would still hold true, but the reverse is true in this case, indicating that other factors are influencing the standing crop of bottom fauna of these two lakes.

Iyengar (1963) pointed out that the chemical composition, growth and multiplication of chironomid larvae are affected mostly by the total carbon content of the lake bottom sediments which would presumably be affected by the turnover rate of plankton. Jonasson (1964) found a relationship between the primary production of phytoplankton and the production of profundal bottom invertebrates. One would expect a higher standing crop of bottom

Figure 22. Relative abundance of major benthic groups in bottom samples taken from Lac La Biche and Beaver Lake.

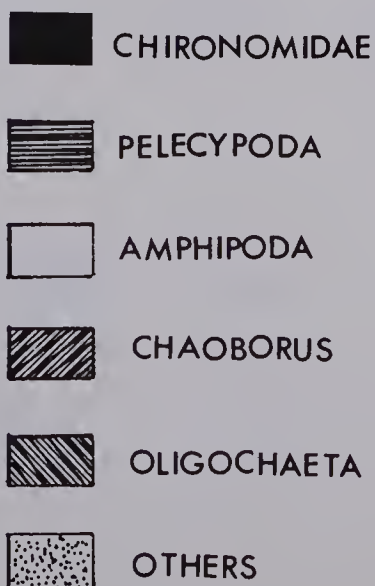
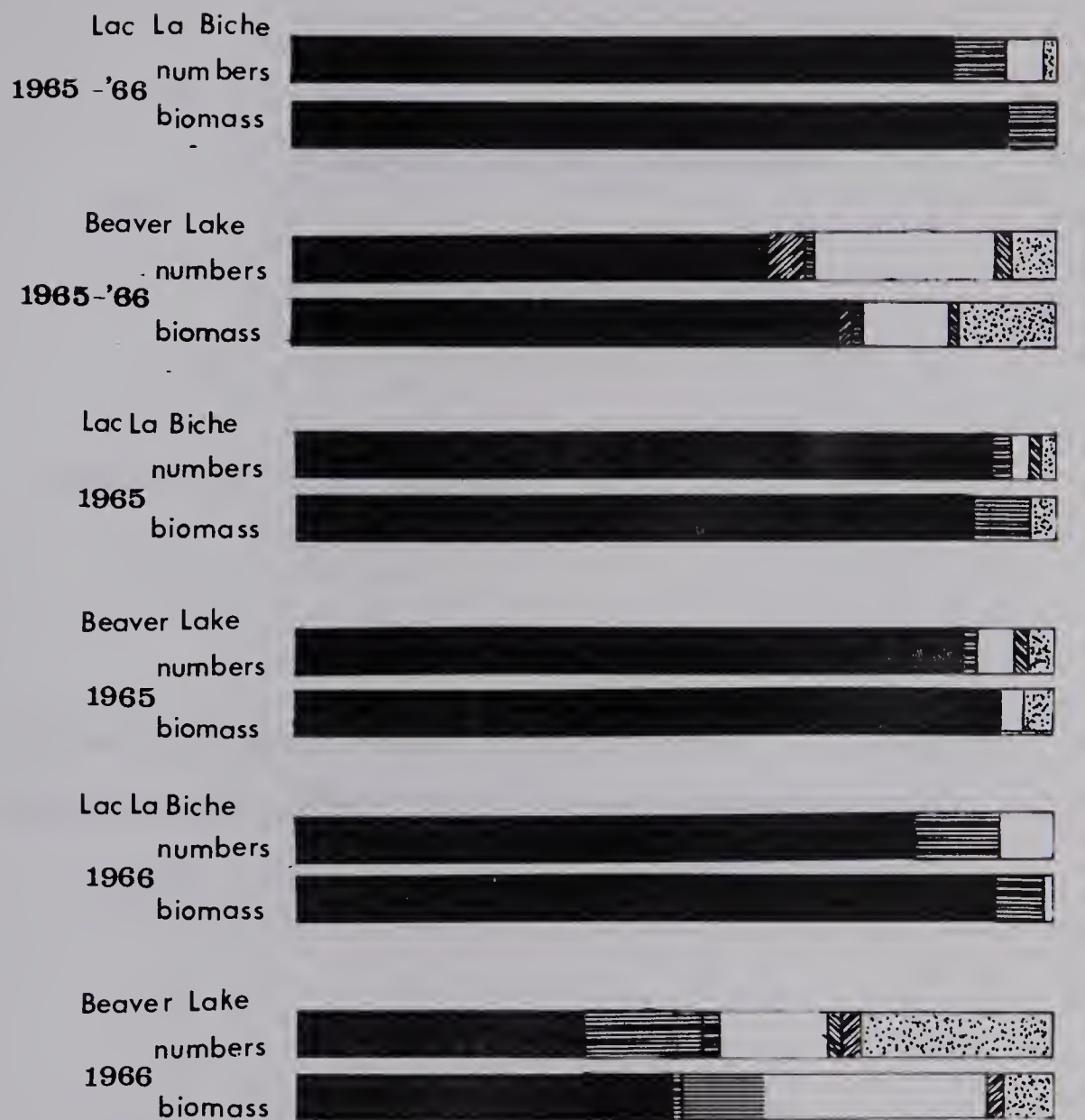


Figure 23. Relationship between numbers and wet weight biomass of bottom fauna from Beaver Lake and Lac La Biche.

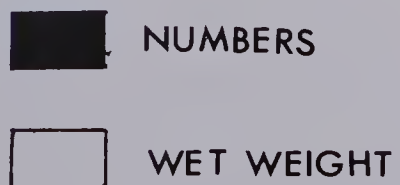
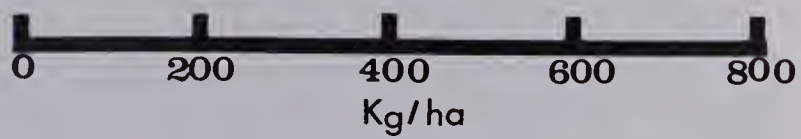
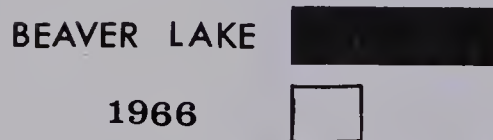
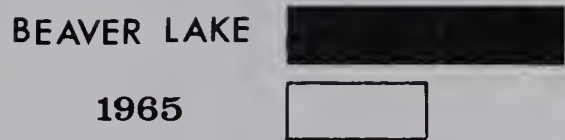
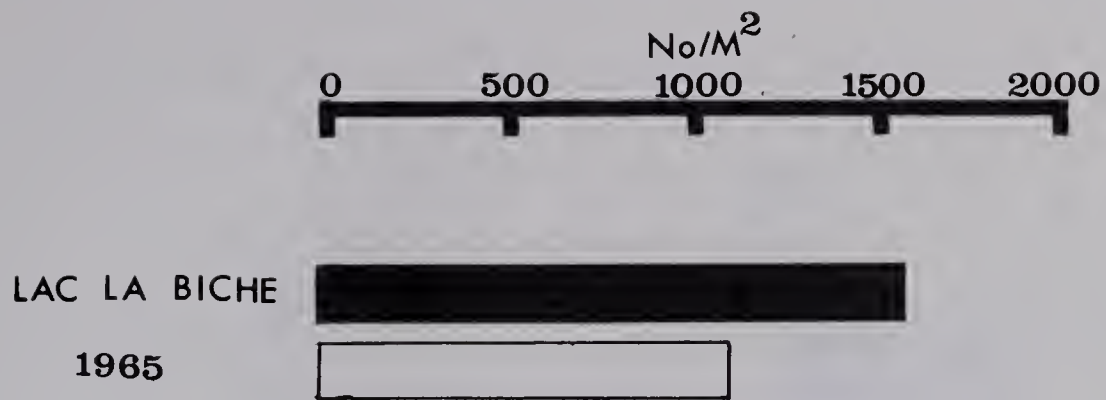
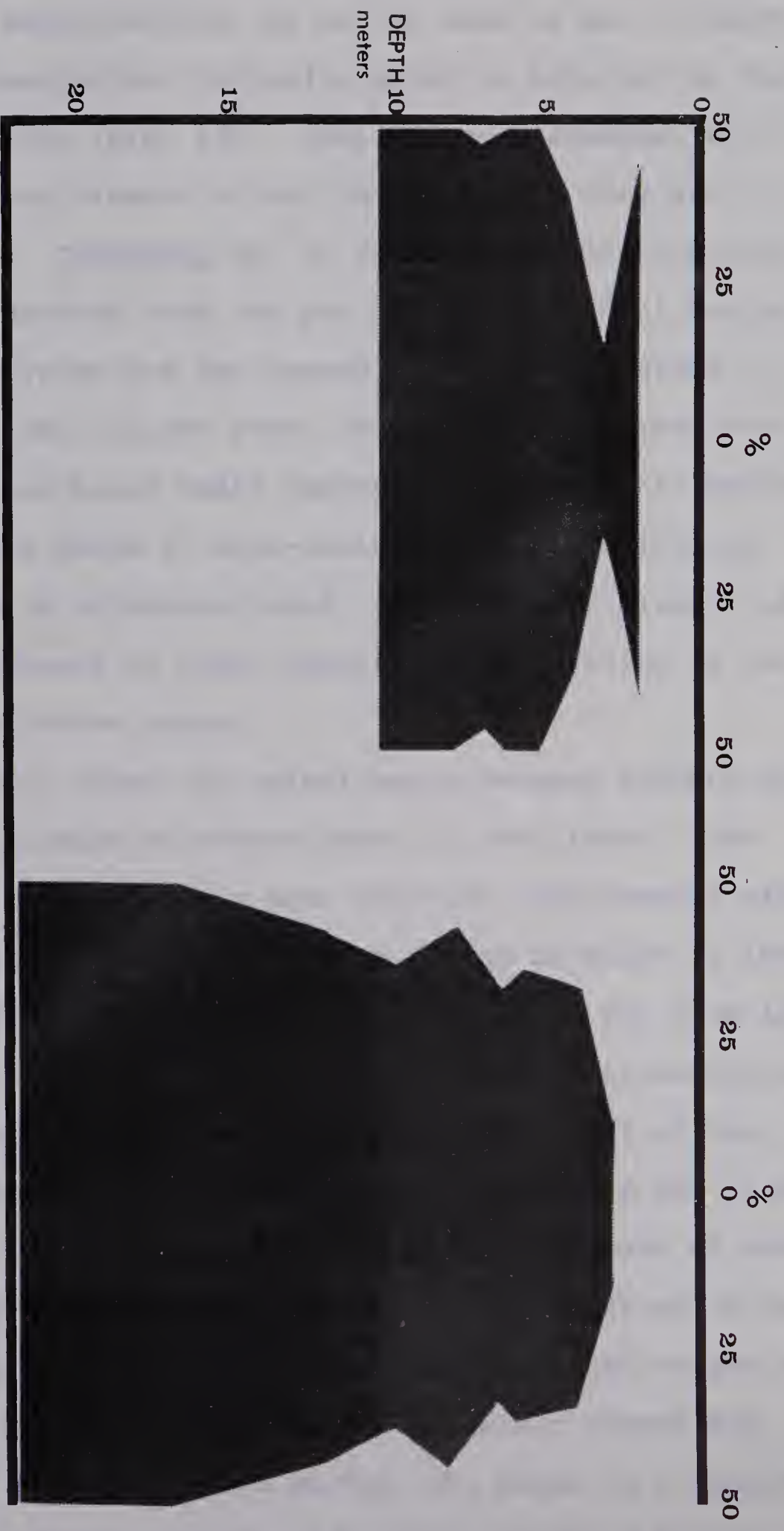


Figure 24. Percentage of Chironomidae in total bottom fauna at varying depths in samples taken from May to September, 1965.



BEAVER LAKE

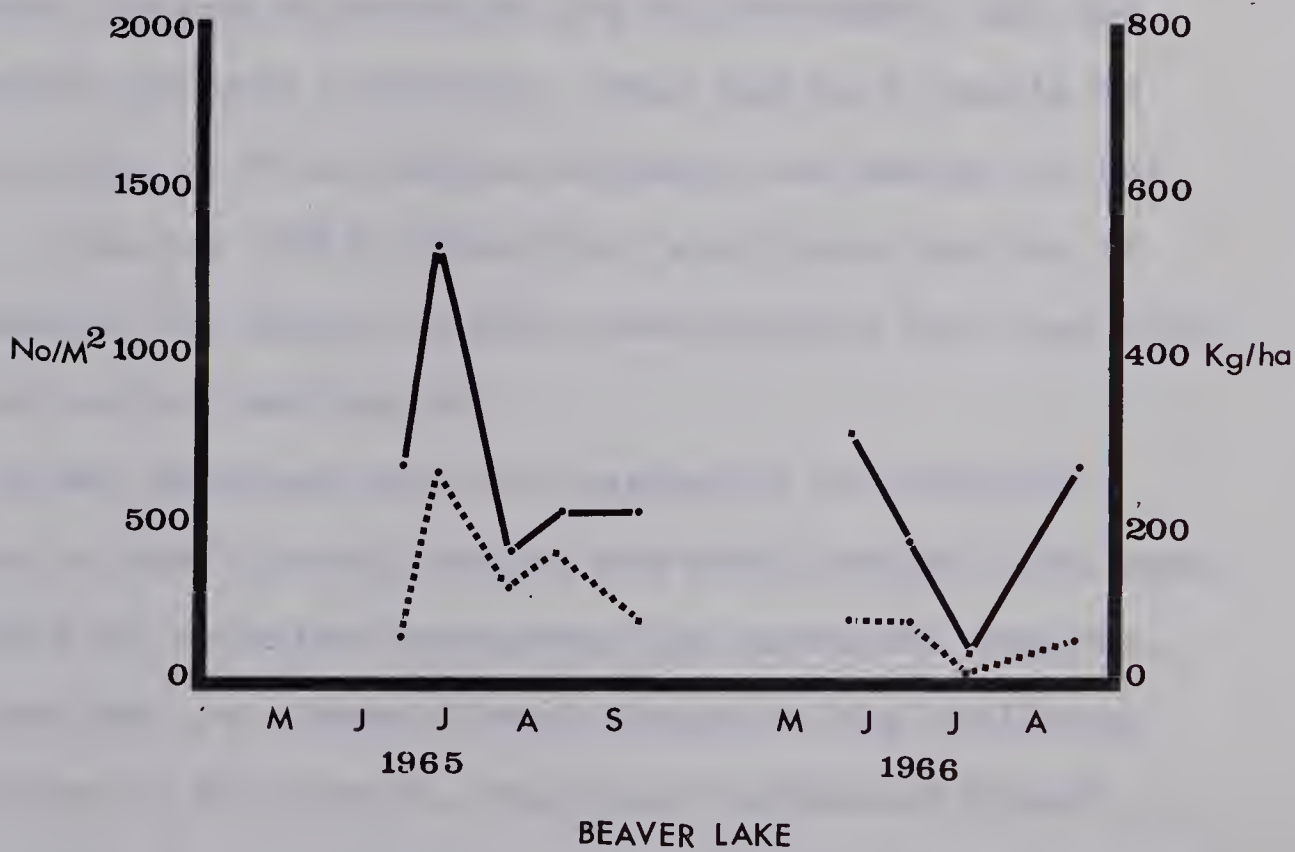
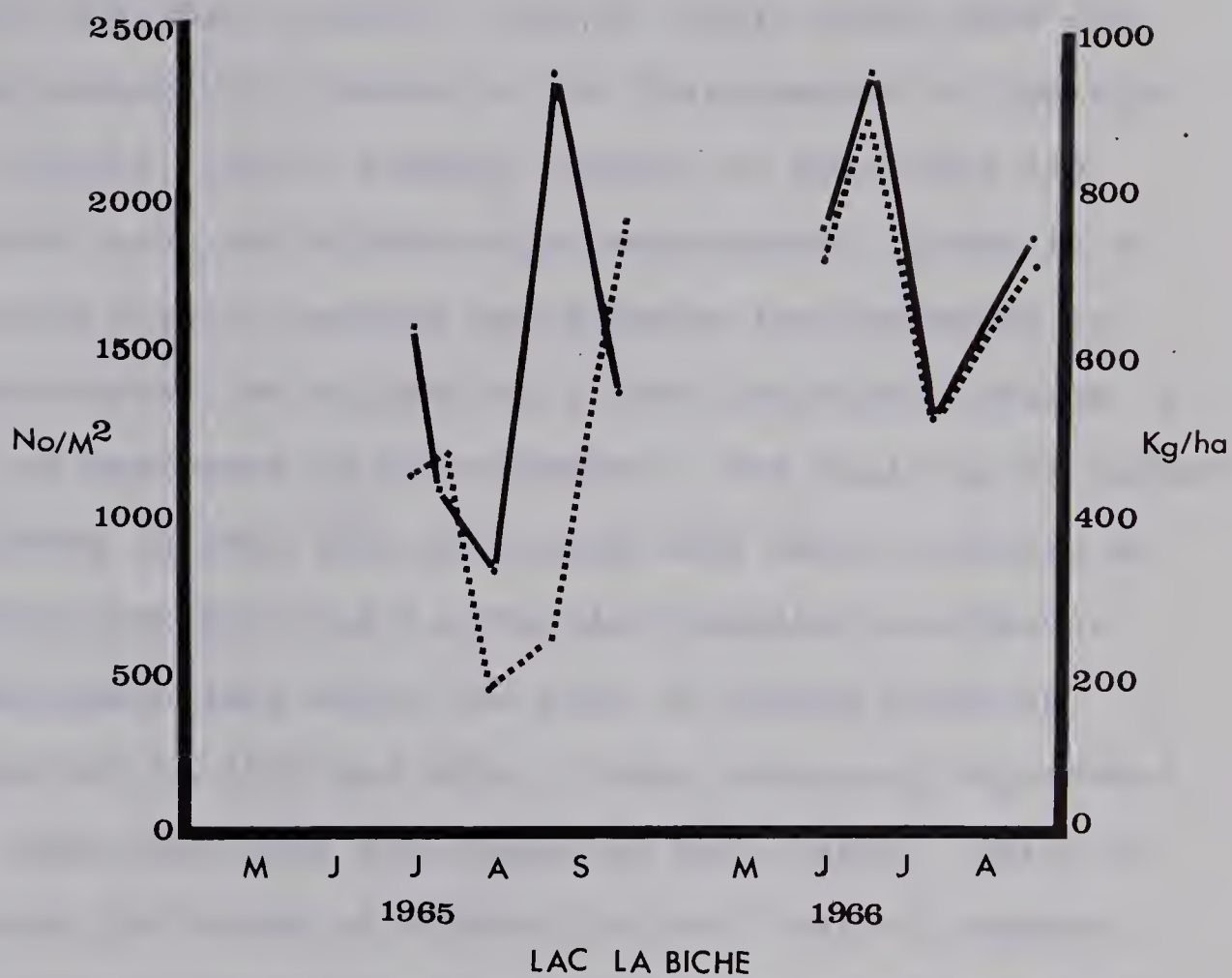
LAC LA BICHE

invertebrates in a lake which had a high primary production of phytoplankton, as is the case in Lac La Biche.

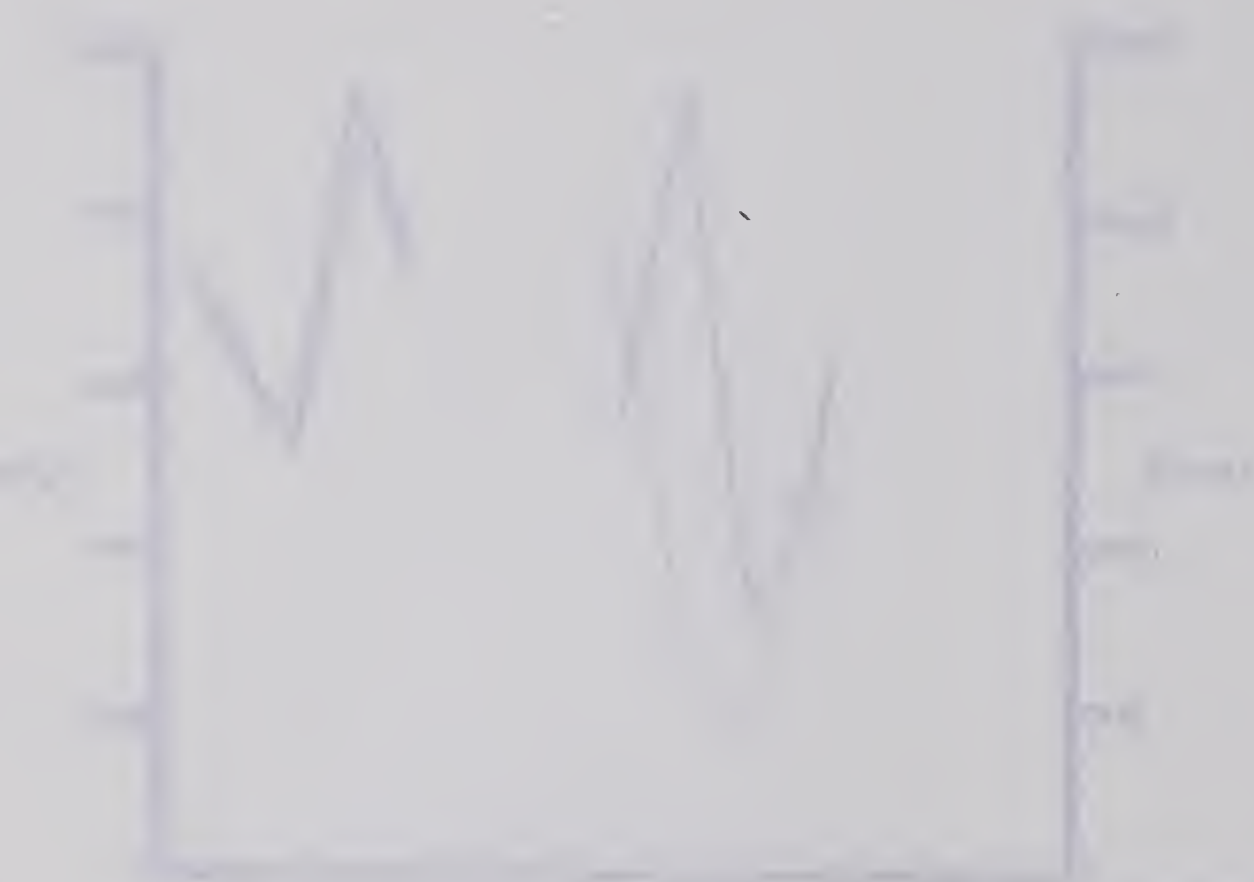
Chironomidae are the major group in both Lac La Biche and Beaver Lake (Fig. 22). They are more abundant both in numbers and biomass in Lac La Biche than they are in Beaver Lake. Chaoborus sp. is found in Beaver Lake only, in numbers greater than one per cent of the total bottom fauna. Amphipoda are the second most abundant group in the lakes. Most of the forms obtained in dredgings were very small and hence their importance in the total make-up of the bottom fauna is over-estimated when considering the numbers of organisms found. In this case biomass is a better estimate of their importance in relation to the rest of the bottom fauna.

Figure 23 shows the relationship between numbers and wet weight biomass of bottom fauna in both lakes. The weight and numbers show a near constant relationship with the exception of the bottom fauna of Lac La Biche in 1966. Kerekes (1964) found no such relationship in the five lakes in central Alberta that he studied. This relationship may be valid in consideration of the long term mean of biomass and numbers; it varies considerably within the lakes throughout the summer period. Since a large part of both numbers and biomass is due to the chironomid fauna of the bottom muds (Fig. 24), the relationship between weight and numbers is mostly a function of chironomid growth and emergence. As can be seen in Fig. 25, there is a considerable variation in both numbers and biomass of bottom fauna in

Figure 25. Seasonal variation in numbers and wet weight biomass of bottom fauna in samples from Beaver Lake and Lac La Biche.



— NUMBERS
 WET WEIGHT



mid-July and early August. Miller (1941) found much the same situation with regard to the Chironomidae of Costello Lake, Ontario. The benthic regions of that lake had emergence times correlated with temperature. There is a high point both in numbers and biomass just previous to the mid-summer low so one may assume the marked change is due to an emergence of Chironomidae. The build up of numbers and biomass in late June and early July would indicate an emergence just previous to the time sampling was begun. This emergence just after the time of spring break-up was observed in 1965 and 1966. Large swarms of chironomid adults were seen near the shores of both lakes. While in most cases the graph of biomass follows that of numbers, in the fall of 1965 in Lac La Biche there seems to be an emergence between mid-August and mid-September but the wet weight biomass increases. This may be a result of other groups of Chironomidae which do not emerge in the fall. Jonasson (1964) found that with some species of chironomids the period of fall overturn was the time that the most weight was gained.

It was observed that the variation in available habitat in the littoral region was much greater than that available to organisms occupying the profundal regions. This resulted in a more diverse fauna in the shallower areas than in the depths, which were inhabited almost exclusively by Chironomidae. Fig. 24 shows the increasing percentage of Chironomidae making up the total bottom fauna as the depth increases in both Lac La Biche and Beaver Lake.

It was impossible to sample the very shallow reaches of the bottom quantitatively due to the extensive growth of rooted aquatic plants present during the summer.

Fillion (1963, 1967) found most chironomid species in Barrier Reservoir, Alberta to be most abundant at the region of maximum drawdown, in part comparable to the littoral region of lakes. In Lac La Biche and Beaver Lake there is in general a maximum number of chironomidae in the littoral areas and a decrease in numbers as depth increases, with the exception of the deepest portions of Lac La Biche, which also has a high concentration of this group. There is also a correlation between the type of bottom and the number of Chironomidae. Sandy bottoms, such as those of sampling stations AL4 in Beaver Lake and A4 and A5 in Lac La Biche, make a poor substrate for these larvae (Table XII). The preferred substrate for these forms is gyttja. This bottom type is formed largely as a result of the detritus falling from above and consequent aerobic decay. Although the gyttja is 3 to 4 meters deep in many portions of the lake it is likely that only the top few centimeters are inhabited by Chironomidae. Mortimer (1949) has shown that dissolved oxygen only enters this loose accumulation of decomposed detritus by molecular diffusion, and then is all used up in the first few millimeters of the surface. Hayes (1964) has stated there is no dissolved oxygen further than one centimeter from the mud surface in the lakes he has examined.

Table XI. Standing Crop of Bottom Fauna in Lac La Biche and Beaver Lake.

	Wts. in kg/hect. dry weight		
	Summer, 1965	Summer, 1966	Mean
Beaver Lake	19.30	9.30	14.30
Lac La Biche	57.94	101.28	79.61

Table XII. Mean Number of Chironomidae at Sampling Stations
in Beaver Lake and Lac La Biche, 1965.

<u>Station</u>	<u>Depth</u>	<u>Bottom Type</u>	<u>No. of Chironomidae/M²</u>	<u>Order of Density</u>
Beaver Lake				
A1	2	sandy mud	1263	4
B _L 2	2.5	gyttja	491	5
B _L 4	2.5	sand	129	11
A _L 1	3.5	gyttja	1969	2
C3	3.5	sand	389	6
B _L 3	5	sandy mud	184	9
B _L 1	6	gyttja	184	9
C _L 1	6.5	gyttja	108	12
D2	7.5	gyttja	1832	1
D _L 1	8.5	gyttja	1631	3
D1	9.5	gyttja, gravel	130	10
C1	10	gyttja	346	7
C2	10	gyttja	54	13
A3	10	gyttja	206	8
A2	11	gyttja	54	14

Lac La Biche

A4	3	sand	97	14
A3	3.5	sand	87	15
B1	4	gyttja	5525	2
C3	5	gyttja	1155	9
A1	5.5	gyttja	1385	7
A5	6	gyttja	9580	1
B3	6	gyttja	1884	5
B6	6.5	gyttja	974	10
C4	8	gyttja	1415	6
B5	8	gyttja	476	13
A2	8.5	gyttja	909	11
B4	9	gyttja	1169	8
B2	12	gyttja	596	12
C2	17	gyttja	2447	4
C1	22	gyttja	2641	3

The maximum number and mass of bottom fauna found during the sampling of Beaver Lake and Lac La Biche during 1965 and 1966 were found on August 20, 1965 at station A5 in Lac La Biche. This was a concentration of 35,593 individuals per square meter made up of 35,276 Chironomidae and 217 Sphaeriidae. They had a wet weight biomass of 2,030 kg/ha.

4. Plankton and Seston

a. Littoral zooplankton

Table XIII is a list of the species of zooplankton found in samples taken from the littoral areas of Lac La Biche and Beaver Lake in August of 1966 with a Birge cone net. Daphnia magna was not taken at this time but was found in very large "swarms" in Lac La Biche on June 20, 1966. These large groups were found in association with large numbers of notonectids in shallow water along a rocky shore. This was the only time during the study this species was found. Two species of Alonella were found in Lac La Biche but none were recorded from Beaver Lake. The most common Cladoceran in the littoral areas of both lakes, Camptocercus rectirostris, was abundant in areas of heavy growths of rooted aquatic plants.

Beaver Lake has a more diverse collection of Copepoda than does Lac La Biche. Eucyclops agilis and Paracyclops fimbriatus poppei were found only in Beaver Lake. The only harpacticoid found during the study was Maraenobiotus insignipes, which occurred on rooted aquatic plants. In

Table XIII. Littoral Zooplankton of Lac La Biche and
Beaver Lake.

	Beaver Lake	Lac La Biche
Cladocera		
<u>Diaphanosoma brachyurum</u> (Lieuen)	x	x
<u>D. leuchtenbergianum</u> Fischer	x	x
<u>Daphnia ambigua</u> Scourfield	x	
<u>D. galatea</u> Sars	x	x
<u>D. magna</u> Straus		x
<u>D. pulex</u> Leydig	x	x
<u>D. retrocurva</u> Forbes		x
<u>D. thorata</u> Forbes		x
<u>Ceriodaphnia quadrangula</u> (O.F. Muller)	x	x
<u>Bosmina coregoni</u> Baird	x	
<u>Camptocercus rectirostris</u> Schodler	x	x
<u>Eurycercus lamellatus</u> (O.F. Muller)	x	x
<u>Alonella</u> sp.		x
<u>Alonella nana</u> (Baird)		x
<u>Pleuroxus procurvus</u> Birge	x	x
<u>P. striatus</u> Schodler		x
<u>Chydorus sphaericus</u> (O.F. Muller)	x	x
Copepoda		
Cyclopoida		
<u>Cyclops vernalis</u> Fischer	x	x
<u>Eucyclops agilis</u> (Koch)	x	
<u>Macrocylops albidus</u> (Jurine)	x	x
<u>Paracyclops fimbriatus poppei</u> (Rehberg)	x	
Calanoida		
<u>Diaptomus oregonensis</u> Lilljeborg	x	x
Harpacticoida		
<u>Maraenobiotus insignipes</u> (Lilljeborg)	x	x
TOTAL	16	19

some littoral areas in Lac La Biche, large numbers of the flagellated alga, Ceratium hirundinella (O.F.M.) were found. No concentrated survey of the algae of the littoral region was undertaken.

In both lakes there is a quite distinct separation of the littoral and limnetic zooplankton communities. This distinction is not maintained to the same degree in the littoral areas that are open to heavy wave action or are exposed to the open areas of the lakes. In these areas some zooplankters more characteristic of the limnetic areas, such as Diaptomus oregonensis, Cyclops vernalis, Chydorus sphaericus, Daphnia retrocurva and Diaphanosoma leuchtenbergianum are found.

Sixteen species of cladocerans and copepods were found in the littoral areas of Beaver Lake and 19 species were found in the corresponding areas of Lac La Biche.

b. Limnetic Phytoplankton

i. Qualitative

The relative abundance of limnetic phytoplankton and the forms occurring in Lac La Biche and Beaver Lake are shown in Table XIV. Seven more forms were found in Beaver Lake than in Lac La Biche. In general, the relative abundance of the forms is much the same in both lakes. Those abundant in one lake are usually found in abundance in the other lake but not necessarily at the same time.

Carefoot (1959) recorded only three species from Lac La Biche; Melosira granulata (Ehrenberg), Stephanodiscus

Table XIV. Limnetic Phytoplankton of Lac La Biche and
Beaver Lake.

	Beaver Lake	Lac La Biche
Cyanophyta		
<u>Anabaena flos-aquae</u> (Lyngbye)	bloom	bloom
<u>A. spiroides</u> Lemm.	bloom	bloom
<u>Aphanizomenon flos-aquae</u> (L.)	bloom	bloom
<u>Microcystis aeruginosa</u> Kuetz	bloom	bloom
<u>Microcystis</u> sp.	abundant	abundant
<u>Gleotrichia echinulata</u> (Smith)	abundant	abundant
<u>Lyngbya</u> sp.	abundant	abundant
<u>Chroococcus</u> sp.	rare	rare
<u>Sphaerocystis schroteri</u> Chod.	rare	rare
<u>Oscillatoria princeps</u> Vaucher	rare	none
<u>Coelosphaerium</u> sp.	common	rare
<u>Chamaesiphon</u> sp.	rare	rare
Chrysophyta		
<u>Asterionella formosa</u> Hass.	common	abundant
<u>Stephanodiscus astraea</u> Ehr.	bloom	bloom
<u>Fragillaria capucina</u> Desm.	abundant	abundant
<u>Melosira</u> sp.	abundant	none
<u>Cerasterias irregulare</u> Smith	rare	none
<u>Staurastrum</u> sp.	rare	rare
<u>Navicula</u> sp.	common	common
<u>Surirella</u> sp.	common	none
<u>Cosmarium</u> sp.	rare	none
<u>Cyclotella</u> sp.	abundant	abundant
<u>Synedra</u> sp.	common	common
<u>Cymbella</u> sp.	rare	rare
<u>Pinnularia</u> sp.	rare	rare
<u>Gyrosignia</u> sp.	rare	none
<u>Cocconeis</u> sp.	rare	rare
Chlorophyta		
<u>Tribonema</u> sp.	abundant	abundant
<u>Pediastrum boryanum</u> (Turp)		
Meneghini	common	rare
<u>Pediastrum</u> sp.	rare	none
<u>Franceia</u> sp.	rare	rare
<u>Chlorococcum</u> sp.	rare	rare
<u>Scenedesmus</u> sp.	rare	rare
<u>Chaemisiphon</u> sp.	rare	rare
Pyrrophyta		
<u>Ceratium hirundinella</u> (O.F.M)	common	common
<u>Dinobryon</u> sp.	rare	rare
TOTAL	36	29

niagarae Ehrenberg and Ceratium hirundinella. It is not stated how or when these specimens were taken. Melosira sp. and Ceratium hirundinella were taken in Beaver Lake but no Melosira sp. were found in Lac La Biche. Stephanodiscus astraea was taken in Lac La Biche, but not the species mentioned by Carefoot.

Rawson (1956) classified lakes in Western Canada as eutrophic, mesotrophic or oligotrophic, according to their dominant algal types. Lac La Biche and Beaver Lake would be eutrophic if one was to consider the blue-green species which bloomed there. However, blooming of Stephanodiscus sp. and Fragilaria sp. would make one tend to consider these lakes mesotrophic according to Rawson's system. Hutchinson (1967) pointed out that many mixed types of dominant algal groups are found, particularly combinations of diatoms. According to Hutchinson's classification of dominant limnetic algal types, the plankton of Lac La Biche and Beaver Lake would be a combination of eutrophic diatom plankton and eutrophic myxophycean plankton.

Unfortunately, the author lacked the necessary keys and equipment and skill to identify most of the Chlorophyta in the field. These forms do not preserve in a state amenable to identification and as a result many of them remained unidentified. These forms did not play a major role in the phytoplanktonic community of either lake.

ii. Quantitative

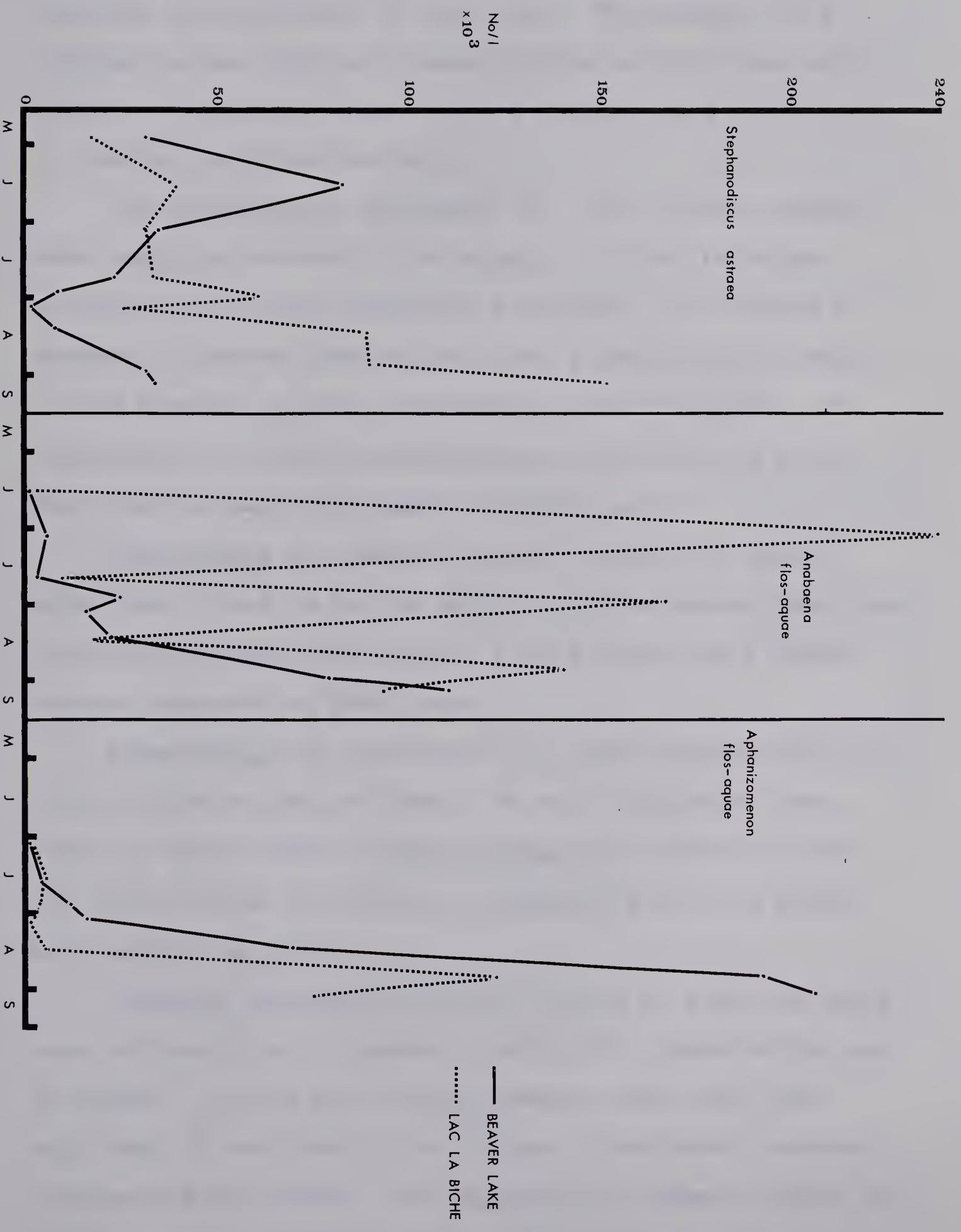
Several species of algae went through pulses or bloom stages throughout the summer of 1966. The most pronounced of these was Anabaena flos-aquae (Fig. 26b) particularly in Lac La Biche. It was not evident until June, then in two weeks time rose from none per liter to 238,000 per liter. This was followed by a rapid drop and two slightly lesser blooms. The only diatom which played a large role in the blooming of alga over the summer was Stephanodiscus astraea (Fig. 26a). It displayed a spring maximum of numbers in Beaver Lake and a fall maximum in Lac La Biche. In general the only algae that showed a nearly identical time of blooming and comparable numbers in the two lakes was Aphanizomenon flos-aquae (Fig. 26c). This species exhibited a single fall pulse in Lac La Biche and Beaver Lake. The dominance of one species in the spring, such as I found to be the case with Stephanodiscus astraea, Lund (1964) attributes to excess nutrients at the end of winter.

Figure 27 illustrates the seasonal succession of algae in Lac La Biche and Beaver Lake. This figure is plotted with the log values of the actual numbers of individuals per liter. This was necessary to deal with the large number of species concerned in a limited space so that a succession could be shown. This method of graphing has the disadvantage of showing a change in population size from 100 to 1,000 as the same as that from 1,000 to 10,000 and so on. Absolute numbers of some dominant algae found throughout the sampling period are shown in Figure 26.

Figure 26a. Seasonal change in numbers of Stephano-
discus astra during 1966.

Figure 26b. Seasonal change in numbers of Anabaena
flos-aquae during 1966.

Figure 26c. Seasonal change in numbers of Aphani-
zomenon flos-aquae during 1966.



When sampling started on May 25, 1966, the diatom Stephanodiscus astraea was well into a pulse and was the dominant phytoplankter at that time. The numbers of S. astraea during 1966 were lowest during mid-July and early August. From early August onward numbers were building up to another bloom in the fall.

The chlorophyte, Tribonema sp., was already abundant when sampling started in the spring. In Lac La Biche at this time it was undergoing a decline. It reached a maximum in Beaver Lake during June, a period during which it was present in very low numbers in Lac La Biche. It was present in bloom concentration in mid-July in Lac La Biche and in early September in Beaver Lake.

Fragillaria sp. reached greater numbers in Beaver Lake than it did in Lac La Biche. A pulse during late June was seen in Beaver Lake only. A fall pulse, of a lesser degree, occurred in both lakes.

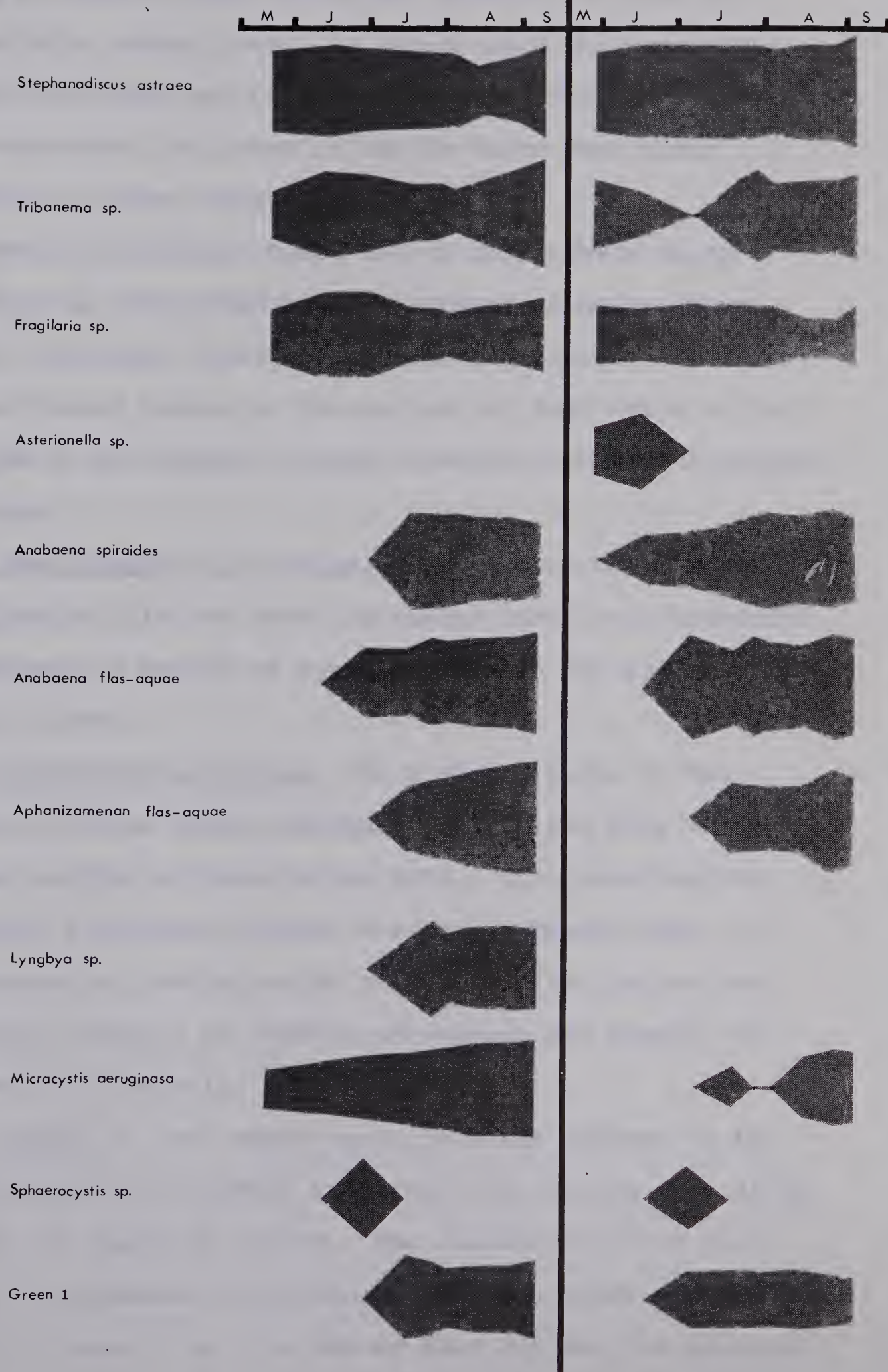
Asterionella sp. occurred in a single short pulse in Lac La Biche in June of 1966. No such occurrence took place in Beaver Lake. Sphaerocystis sp. underwent short and small blooms at nearly an identical period in Beaver Lake and Lac La Biche.

Anabaena spiroides was found in Lac La Biche in early June and built up in numbers steadily to a peak at the end of August. It did not occur in Beaver Lake until mid-July when it was found in an intense bloom which remained for most of the summer. It decreased in numbers during the fall overturn. Anabaena flos-aquae was the species

Figure 27. Seasonal succession of dominant phytoplankters during 1966. All values are expressed as natural logarithms of the actual number of individuals per liter.

BEAVER LAKE

LAC LA BICHE



exhibiting the most extreme blooms in Lac La Biche. A series of three blooms, short but intense occurred in Lac La Biche during 1966. In Beaver Lake the same three pulses took place but to a far lesser extent. The very high concentrations found in Lac La Biche were never recorded in Beaver Lake.

The alga labelled Green 1 is a chlorophyte which could not be identified but was present in quite large numbers throughout most of the sampling period. In Beaver Lake it showed pulses in the spring and fall while in Lac La Biche it was present in near constant numbers throughout the summer.

Aphanizomenon flos-aquae, a bloom species of wide distribution, did not occur in either lake until mid-July. It underwent a period of intense bloom in the fall of 1966 in both lakes.

Microcystis aeruginosa had a slight pulse in the spring in Lac La Biche, disappeared and then went through another period of bloom in the fall. This same species had quite a different summer history in Beaver Lake. It was present at the beginning of the sampling period and increased steadily in numbers throughout the summer, to a maximum in the fall.

Lyngbya sp. was never found in large numbers in Lac La Biche but was abundant in Beaver Lake during the latter half of the sampling period. The concentration of this species is somewhat misleading. It was present only rarely in areas 1 to 3 in Beaver Lake but was the dominant

form in the southernmost part of the lake, area 4. Since usually only one phytoplankton sample was taken in this area out of a total of four, the mean value used gives a somewhat misleading idea of the importance this phytoplankter in Beaver Lake. The reason for this very localized concentration in Beaver Lake is unknown.

Hammer (1964) studied a number of lakes in southern and central Saskatchewan and found Anabaena flos-aquae to have two major pulses, in late spring and late summer, he found these blooms usually of short duration. He found that Aphanizomenon flos-aquae was rare until the temperature was about 20 C and most blooms occurred when the water was from 22.5 to 26.5 C. Microcystis aeruginosa he found to have a wide range of temperature tolerance but generally bloomed when waters were above 20 C. He states the usual bloom succession in the lakes he studied to be Anabaena; Microcystis; Aphanizomenon. The succession of blooming of the three species of Cyanophyta was found to occur: Anabaena; Aphanizomenon; Microcystis in Lac La Biche in 1966 and in the same order but to a lesser degree in Beaver Lake in 1966.

c. Limnetic Zooplankton

i. Qualitative

The species of zooplankton occurring in the limnetic regions of Beaver Lake and Lac La Biche are shown in Table XVI. The rotifers occurring in the lakes were most abundant in the early summer, just after the ice had left the lakes.

Table XV. Time of Blooming for the Dominant Forms of
Phytoplankton in Beaver Lake and Lac La Biche.

	<u>Beaver Lake</u>	<u>Lac La Biche</u>
Spring	<u>Stephanodiscus astraea</u>	<u>Stephanodiscus astraea</u>
	<u>Tribonema</u> sp.	<u>Tribonema</u> sp.
	<u>Fragillaria</u> sp.	<u>Fragillaria</u> sp.
		<u>Asterionella</u> sp.
Summer	<u>Anabaena spiroides</u>	
	<u>Lyngbya</u> sp.	
	Green 1	Green 1
		<u>Anabaena flos-aquae</u>
Fall	<u>Anabaena flos-aquae</u>	
	<u>Aphanizomenon flos-aquae</u>	<u>Aphanizomenon flos-aquae</u>
	<u>Microcystis aeruginosa</u>	<u>Microcystis aeruginosa</u>
	<u>Stephanodiscus astraea</u>	<u>Stephanodiscus astraea</u>
	<u>Tribonema</u> sp.	<u>Tribonema</u> sp.
	<u>Fragillaria</u> sp.	<u>Fragillaria</u> sp.
		<u>Anabaena spiroides</u>

Species of Keratella were the most abundant rotifers in both lakes. Asplanchna priodonta was nearly as prevalent as Keratella spp. during the early summer.

The only species of the limnetic zooplankton which was not found in both lakes was the large predacious cladoceran, Leptodora kindtii, which was found on two occasions in Lac La Biche. Reed (1964) found this form in several of the larger lakes in Saskatchewan.

The copepod fauna of the limnetic regions of the study lakes consists of four species and is much what one would expect. Pennak (1953) states, "In most lakes the limnetic copepod plankton is rather monotonous; usually it is composed of only one, two or three species,". This lack of diversity of species in the limnetic region of the lakes is no doubt due to the uniformity of habitat. This probably allows sudden increases in populations to take place.

Daphnia retrocurva and Chydorus sphaericus were the most prevalent cladoceran forms in the lakes. The other species were rarely encountered. Diaptomus oregonensis and Cyclops vernalis were the most abundant Copepoda, others being rare.

Reed (1963) reported Daphnia retrocurva from Lake Athabaska in Alberta, Bosmina coregoni from Wollaston Lake in Saskatchewan, Chydorus sphaericus from the same lake in Saskatchewan, as well as Diaphanosoma brachyurum and Leptodora kindtii. He reports having found Diaptomus minutus and D. oregonensis in Lakes Athabaska and Wollaston respectively. Cyclops navus and C. vernalis were found by

Table XVI. Species of Limnetic Zooplankton Occurring
in Lac La Biche and Beaver Lake.

	Beaver Lake	Lac La Biche
Rotifera		
<u>Branchionus</u> sp.	x	x
<u>Keratella</u> spp.	x	x
<u>Asplanchna priodonta</u> Gosse	x	x
<u>Kellicottia longispina</u> Ahlstrom	x	x
<u>Filinia longiseta</u> (Ehrenberg)	x	x
Cladocera		
<u>Daphnia retrocurva</u> Forbes	x	x
<u>Daphnia thorata</u> Forbes	x	x
<u>Ceriodaphnia</u> sp.	x	x
<u>Bosmina coregoni</u> Baird	x	x
<u>Chydorus sphaericus</u> (O.F.M.)	x	x
<u>Diaphanosoma leuchtenbergianum</u> Fischer	x	x
<u>Leptodora kindtii</u> (Focke)	-	x
Copepoda		
<u>Diaptomus minutus</u> Lilljeborg	x	x
<u>Diaptomus oregonensis</u> Lilljeborg	x	x
<u>Cyclops vernalis</u> Fischer	x	x
<u>Cyclops navus</u> Herrick	x	x

Reed in the Canadian subarctic. Since Lac La Biche and Beaver Lake are in the same lake region as these lakes and are comparable in many other respects, it might be expected that these forms should be found in the two lakes, as they are shown to be in Table XVI.

ii. Quantitative

Figure 28 indicates seasonal changes in the population sizes of the four dominant zooplankters in the lakes. The numbers per liter shown in Figure 28 and Table XVII are no doubt somewhat lower than the actual values due to the problems inherent with sampling with a plankton net. Ricker (1932) stated that a new net might sample as little as one fifth of the column through which it moves and an old net as little as one fourteenth. Langford (1953) indicates a net captures about one quarter as much plankton as a plankton trap. If the concentrations of zooplankters were multiplied by a factor of about 5 perhaps a more meaningful relationship between them and the concentration of phytoplankton could be obtained. This was not done since population changes and the species relationships to each other are easily seen without adding a further source of error.

In general Beaver Lake has a larger population of zooplankton per unit volume than has Lac La Biche. Cyclops vernalis is the dominant form in Beaver Lake throughout the summer period but is only dominant during the early spring in Lac La Biche, and then not to the same extent as

occurs in Beaver Lake. The very small form, Chydorus sphaericus becomes the most abundant zooplankter in Lac La Biche during the fall period. It is nearly non-existent during the early part of the summer in Lac La Biche and present only in very small numbers in Beaver Lake during the same period. All four of the dominant species in Beaver Lake and all but Chydorus sphaericus in Lac La Biche exhibit an increase in population size sometime in June followed by a period of low numbers in mid-summer and another increase in the fall, after the fall overturn. Langford (1938) found a similar bimodal tendency in populations of Cyclops sp. and Diaptomus oregonensis in Nipissing Lake in 1934. Hall (1964) considered spring and fall maxima to be attributable to more than just food availability. Populations in Beaver Lake and Lac La Biche cannot be considered bimodal or unimodal in nature without several successive years of data. With the exception of Chydorus sphaericus the dominant zooplankters showed a bimodal tendency in 1966.

Although bimodal tendencies are seen in both Beaver Lake and Lac La Biche, the population fluctuations are not as marked in Lac La Biche as they are in Beaver Lake, with the exception of Chydorus sphaericus. The "leveling off" tendency of all but one of the zooplankters in Lac La Biche is considered to be due to the presence of a planktonivorous fish in Lac La Biche.

Hazelwood and Parker (1961, 1963) found correlations between a number of environmental factors and populations

of Diaptomus leptopus and Daphnia schodleri. The only factor which vary to any degree between Lac La Biche and Beaver Lake is possible food (see phytoplankton and primary production results), with which Hazelwood and Parker found a high negative correlation. They attributed this to the grazing effect of the zooplankton upon the phytoplankton and hence can be considered a result of zooplankton numbers, rather than the reverse situation. Tappa (1965) found a close relation between commonly found phytoplankton and that occurring in the gut of Daphnia, except for large forms, such as Ceratium, which supports the conclusion of Hazelwood and Parker. Since all the parameters considered are nearly the same in Lac La Biche and Beaver Lake yet a large difference in zooplankton numbers does exist, one might consider these differences due to some other factor. The tullibee, Leucichthys sp., is a planktonivore existing only in Lac La Biche. Brooks and Dodson (1965) found that a fresh-water planktonivore can effectively reduce the numbers of large zooplankters in a lake. Such could well be the case in Lac La Biche.

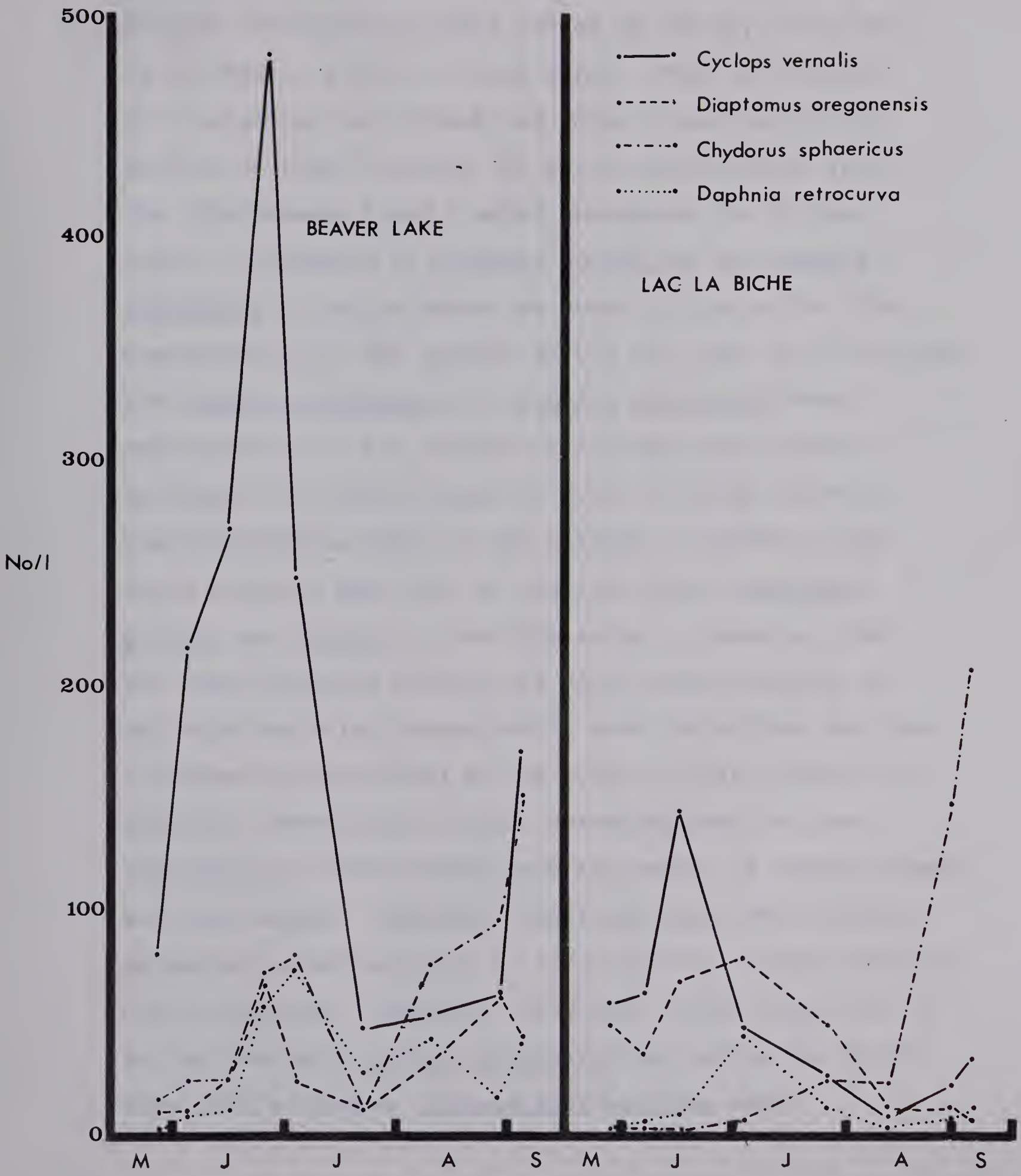
Pennak (1957) found the majority of limnetic communities are characterised by the presence of one dominant copepod, one dominant cladoceran and one dominant rotifer. The rotifers in Lac La Biche and Beaver Lake were found only during the spring and then in low numbers. Three samples taken in December, 1966 (Table XVIII) show Asplanchna sp. to be very dominant during the winter period. Cyclops vernalis and Chydorus sphaericus are the dominant copepod

and cladoceran throughout most of the summer period in both lakes. Pennak stated that if more than one species of cladoceran or copepod occur in the same lake it is unusual to find more than one species in the same genus. It is seen from Table XVI that two species of Cyclops and two species of Diaptomus were found in both lakes. Rigler and Langford (1967) found Diaptomus oregonensis and Diaptomus minutus, the two species found in Lac La Biche and Beaver Lake, occurring in 45 of 100 lakes they studied in Ontario. Pennak pointed out that when two species of the same genus do occur in the same lake, one is at least twenty times as abundant as the other. This was found to be the case in both Beaver Lake and Lac La Biche as Diaptomus minutus and Cyclops navus were rarely found.

It was found during the sampling of zooplankters that large variations often existed between stations in the same lake on the same date. This was no doubt due to concentration of these forms. Ragotzkie and Bryson (1953) found that Daphnia pulex in Lake Mendota were concentrated by wind induced currents in the lake and this resulted in large horizontal variations. Langford (1938) found Diaptomus oregonensis and Cyclops sp. to be grouped horizontally in Lake Nipissing.

A 24-hour study of the diurnal movements of the zooplankton was carried out on Beaver Lake September 6, 1966 and on Lac La Biche on September 7, 1966. Only Cyclops vernalis and Chydorus sphaericus were present in sufficient numbers in Beaver Lake to construct vertical distribution

Figure 28. Seasonal changes in populations of four dominant zooplankters in Lac La Biche and Beaver Lake during 1966.

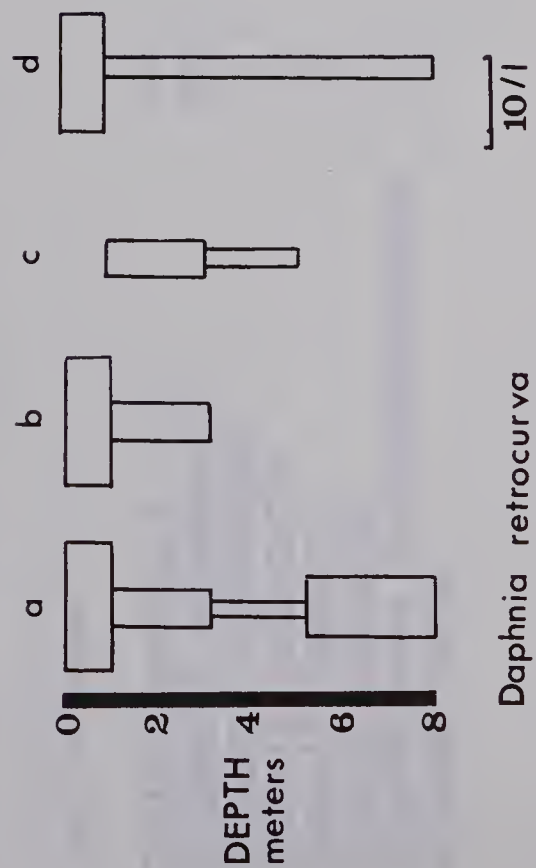
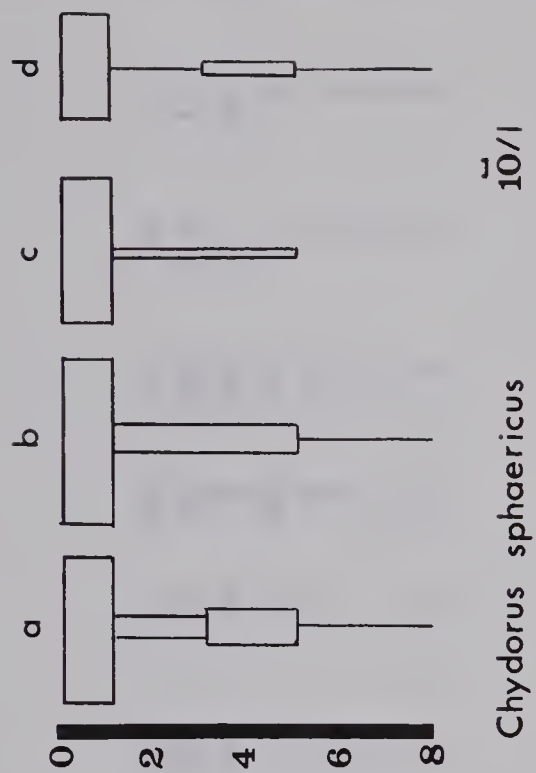
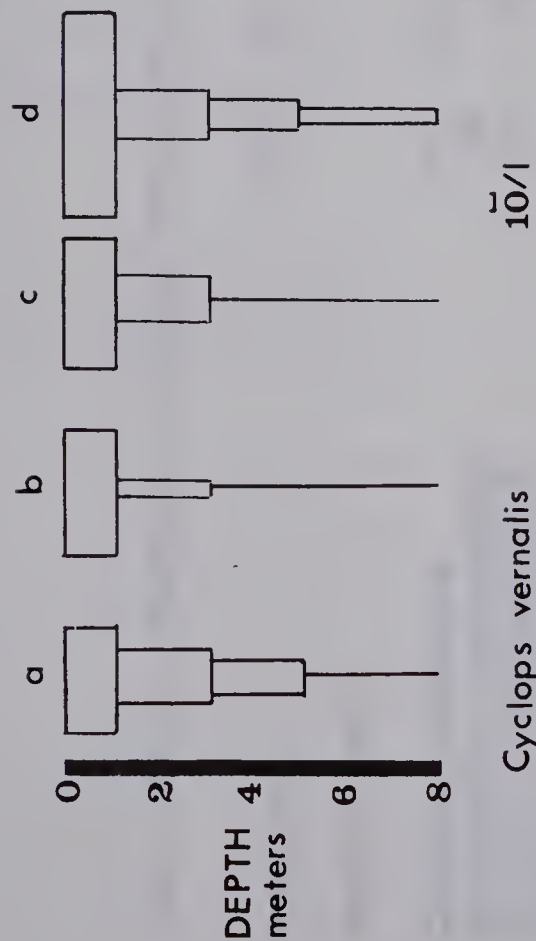
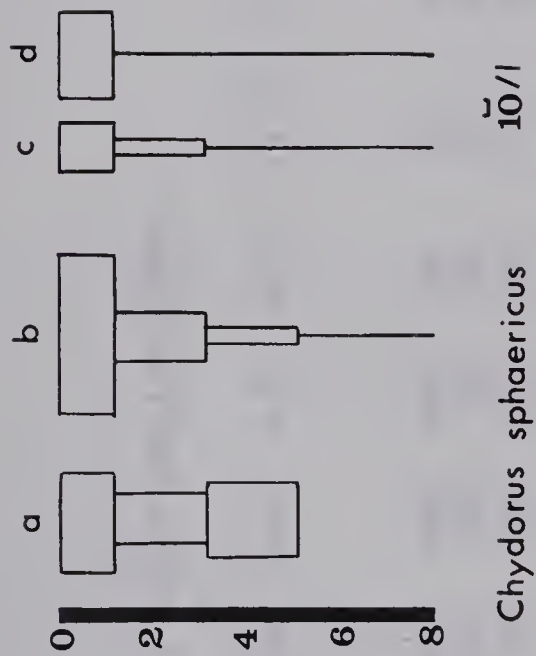


histograms (Fig. 29a). A general concentration at the surface throughout the dark period of the day, from dusk to pre-dawn, is seen in these forms. This is followed by a spreading out through the water column during the periods of light, although the major concentration is in the zone between 0 and 1 meter throughout the 24 hour period. Movements of Chydorus sphaericus and Daphnia retrocurva in Lac La Biche are shown in Figure 29b. No concentration at the surface during the night is discernable for Chydorus sphaericus but Daphnia retrocurva shows a concentration at the surface at midnight and a moving throughout the water column at noon, although the major concentration is still at the surface. Langford (1938) found much the same sort of occurrence with Diaptomus, Cyclops and Daphnia in Lake Nipissing in Ontario. There was some diffusion through the water column through the day with the major concentration near the surface and then a further concentrating at the surface during periods of darkness. Worthington (1931) described much the same phenomenon in Lake Lucerne, only the amount of diurnal change was more marked. McNaught (1966) has found this diurnal migration to be initiated in large part by rapidly changing light intensity. McNaught and Hasler (1966) found this to be the case with Daphnia retrocurva and during the bright days with a copepod, Limnocalanus macrurus Sars.

Figure 29a. Diurnal movements of Cyclops vernalis and Chydorus sphaericus in Beaver Lake during the 24 hour period beginning at dusk, September 6, 1966.

Figure 29b. Diurnal movements of Daphnia retrocurva and Chydorus sphaericus in Lac La Biche during the 24 hour period beginning at dusk, September 7, 1966.

- a - Dusk
- b - Midnight
- c - Dawn
- d - Noon



LAC LA BICHE

Table XVII. Numbers of Major Zooplankters per Liter During 1966.

Species	25/5	9/6	14/6	24/6	4/7	22/7	11/8	29/8	5/9
Beaver Lake									
<u>Cyclops vernalis</u>	80	218	268	482	247	46	53	61	170
<u>Diaptomus oregonensis</u>	8	7	23	65	22	10	28	58	42
<u>Chydorus sphaericus</u>	13	21	23	70	79	10	73	92	150
<u>Daphnia retrocurva</u>	0	7	9	56	73	25	40	15	39
<u>Daphnia thorata</u>	1	0	2	22	37	2	0	0	0
<u>Bosmina coregoni</u>	0	4	3	6	16	0	0	8	20
<u>Diaphanosoma leuchtenbergianum</u>	0	0	0	0	0	0	13	2	2
<u>Ceriodaphnia sp.</u>	0	0	0	0	0	0	3	0	0
Lac La Biche									
<u>Cyclops vernalis</u>	58	62	142	0	45	25	6	21	33
<u>Diaptomus oregonensis</u>	48	34	66	0	78	48	13	11	5
<u>Chydorus sphaericus</u>	1	0	2	0	6	24	20	145	220
<u>Daphnia retrocurva</u>	0	3	7	0	48	10	0	6	10
<u>Daphnia thorata</u>	0	0	0	-	0	0	2	0	0
<u>Bosmina coregoni</u>	0	0	0	-	0	0	0	2	1
<u>Diaphanosoma leuchtenbergianum</u>	0	0	0	-	0	0	2	6	6
<u>Cyclops navus</u>	0	0	0	-	0	4	0	0	0

Table XVIII. Abundance of Zooplankters in Sample Taken
December 27, 1966.

Species	BVL	LLB 1	LLB 3
<u>Asplanchna</u> sp.	230	2,312	983
<u>Diaptomus oregonensis</u>	84	76	9
<u>Daphnia</u> sp.	48	22	0
<u>Cyclops vernalis</u>	70	0	3
<u>Bosmina coregoni</u>	6	182	22

BVL = Beaver Lake

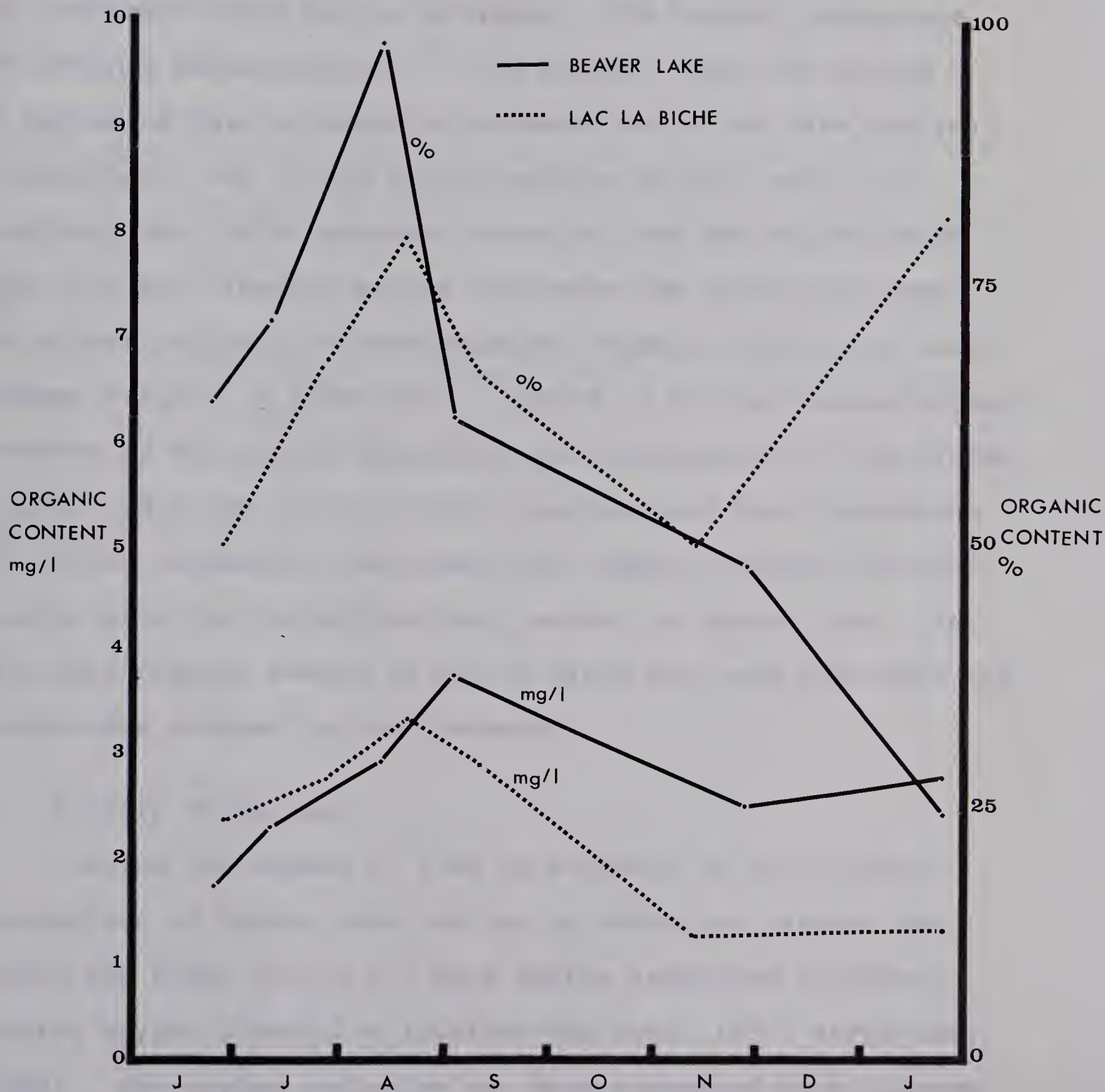
LLB = Lac La Biche

d. Seston

During the summer and early winter periods of 1965 seston samples were taken in Beaver Lake and Lac La Biche. The dry weight and organic matter obtained are shown in Table XIX. These values are the averages of 21 and 19 samples for Beaver Lake and Lac La Biche respectively from June to September. Samples obtained in November and December are not included in this average so the values could be directly compared to those of Kerekes (1965). These values are lower than any Kerekes obtained from his study of five lakes in Central Alberta. This might be expected since the lakes he studied were very shallow (mean depths, 0.78 to 3.32 m). The two lakes had a similar amount of organic matter in them during 1965 with Beaver Lake having only slightly less than Lac La Biche during the summer period (Table XIX). Although seston samples were not regularly centrifuged during 1966, six samples taken on August 22, 1966, were analyzed in this manner to serve as a comparison with 1965. They were found to contain a mean value of 3.50 mg/l in Beaver Lake and 3.45 mg/l in Lac La Biche. These values are only slightly higher, about 0.2 mg/l, than those of a similar date in 1965 (Fig. 30). The organic content of the seston was 60% for Beaver Lake and 61% for Lac La Biche. These values are within the range found by Kerekes, 34% to 74.8%.

In this respect Beaver Lake and Lac La Biche are almost identical: Beaver Lake, 2.59 mg/l and Lac La Biche, 2.65 mg/l. It is unknown what portion of this is plankton and what part detritus. Odum and de la Cruz (1963) point out the important

Figure 30. Seasonal change in organic content of total seston of Beaver Lake and Lac La Biche from June, 1965 to January, 1966.



role played by detritus in the fresh-water ecosystem.

Figure 30 shows the development of organic seston during the latter half of 1965. Organic seston reaches its highest concentration in Lac La Biche in late August and in Beaver Lake in early September. This was just after the fall overturn when an extensive bloom was in progress. The highest percentage of organic material was . . . in August. This was during a period of fairly extensive blooming while the lake was well stratified. Due to the stratification of the lake it is unlikely that much inorganic material from the bottom would get into the limnetic seston and hence the seston was made up almost entirely of autochthonous organic material of quite recent origin. A sharp drop is noted in the percentage organic content of the seston just after the dissolution of the thermocline. This may be due to fall overturn and the disturbance of bottom sediments. Both per cent organic content and total seston were low during the early winter in Beaver Lake. The per cent organic seston in Lac La Biche was very high when the lakes were sampled in late December.

e. Primary Production

During the summer of 1966 an estimate of the primary production of Beaver Lake and Lac La Biche was carried out using the Light Bottle and Dark Bottle technique of determining oxygen production (Gaarser and Gran, 1927; Strickland, 1960). The oxygen evolution was then converted to milligrams of Carbon used (for methods of calculation see Appendix F). Ryther (1956) suggests the use of a photosynthetic quotient (PQ)

Table XIX. Average Summer Dry Weight and Organic Matter
Biomass of Seston of Beaver Lake and Lac La
Biche.

Lake	Dry weight mg/l	Organic matter mg/l	Per cent organic matter
Beaver	4.30	2.59	60%
La Biche	4.37	2.66	61%

of 1.25 in converting the oxygen to carbon values and this value was adopted in this study. He indicated that the light bottle-dark bottle technique is valid in that respiration, as measured in the dark bottle, is found to continue at the same rate whether or not photosynthesis is under progress. The use of oxygen evolution as a measure of photosynthesis has been criticised (Steeman-Nielsen, 1954) as overestimating the rate of carbohydrate production, but Ryther (1956) and McAllister (1961) indicate that if anything, the reverse is true, that measuring oxygen evolution underestimates photosynthetic activity. Goldman and Wietzel (1963) state that measuring oxygen evolution more nearly measures gross production.

The results of the experiments (Table XX) indicate that Lac La Biche has a much higher rate of photosynthetic activity than does Beaver Lake. The overall ratio between the photosynthetic activity of the two lakes during the summer of 1966 is 2.6. During the ten hour period that the samples were suspended in the water the weather was identical at both lakes. The weather conditions during the study days were typical of the general summer weather conditions of the region.

Since only a limited number of determinations of primary production were made, it was thought to be desirable to find the level where the maximum amount of production would be taking place. This was found to be about 1/2 meter below the surface. This was the type 1 situation with regard to photosynthetic activity and depth as presented by Fingenegg (1964). Ohle (1958) found that in addition to the vertical

Table XX. Rates of Primary Production During 1966 in Lac La Biche and Beaver Lake.

Date	Beaver Lake		Lac La Biche	
	mgC/l/hr	mgC/l/day	mgC/l/hr	mgC/l/day
June 30	.015	.360	.048	1.152
July 29	.018	.432	.044	1.056
August 12	.030	.720	.0720	1.728
Mean	.021	.504	.055	1.320

variation, the most active period of photosynthetic activity was in the morning and was much lower in the afternoon. The tests on Beaver Lake and Lac La Biche were done for a ten hour period encompassing both these periods.

VII DISCUSSION

A study of the biota of lakes in this region of the North American continent is essentially a study of the success and extent of post-glacial recolonization. Wynne-Edwards (1952) stated of the water systems of glacial North America, that "their preglacial fauna was exterminated, or endured a climate so severe that few or no freshwater vertebrates survived." The same statement can be echoed for the majority of the invertebrates of this region. Hence recolonization in the last 11,500 to 12,000 years and its success to date in Lac La Biche and Beaver Lake is what is being considered in the present study.

Lac La Biche and Beaver Lake lie in close proximity to each other and hence have nearly identical edaphic and climatic conditions. They exhibit much the same conditions with respect to dissolved oxygen, temperature and other chemical and physical characters. There is some morphometric variation between the two bodies of water which may well influence many of the biological characters of the lakes. However, one of the prime considerations in morphometric analysis, mean depth, is much the same in the two lakes. Another factor of importance is that these two lakes are in no way connected, with Lac La Biche lying in the Mackenzie drainage and Beaver Lake in the Churchill drainage. Even though many of the conditions which were found to be nearly the same are considered important to the biotic composition of lakes, there are many differences between the biotas of Beaver Lake and Lac La Biche.

Most of the differences between the two biotas concern the abundance of the organisms present. Although some differences in the makeup of the communities, especially in terms of taxa present, were found, most of these were of a minor nature. The organisms occurring in only one lake were usually found rarely in that lake and absent in the other. This was in general due to some small difference in the two lakes, as for example in the case of Gyraulus crista, which was found only in Lac La Biche. This form characteristically inhabits shallow pond-like areas with heavy growths of aquatic vegetation. While there is one such region in Lac La Biche, there is no comparable region in Beaver Lake or the species would likely be found there as well. The same is usually true of the other littoral bottom fauna forms found in one or the other of the two lakes. The differences in the qualitative makeup of the lakes are due to the availability or lack of suitable habitat.

One of the most striking differences is found in the fish faunas of the two lakes. Several species present in Lac La Biche, but absent from Beaver Lake occur elsewhere in the Beaver-Churchill drainage, so their absence cannot be explained merely by difference in drainage systems. The most notable instance is the lack of tullibee, Leucichthys sp. in Beaver Lake, which, it would seem, leaves unused a large food niche, that of a limnetic planktonivore.

The problem of standing crop, production and productivity in lakes has long been of interest to limnologists. Rawson (1955) equated standing crop of plankton, bottom fauna and

commercial fish catch to mean depth in an attempt to attain a productivity index. Northcote and Larkin (1956) related the standing crop of a standard net haul to total dissolved solids in a productivity index in British Columbia lakes. However, Hayes and Anthony (1964) pointed out that the relationship of standard net haul and T.D.S. found by Northcote and Larkin failed when applied separately to different geological regions. Ryther (1956) considered standing crop to be a poor index of production without some idea of turnover time, and adds production must be considered as a rate rather than a static quantity. Rohde (1958) and Verduin (1956) found a highly variable but rough indication that a general proportional relation between standing crop and daily production does exist. It seems that in many cases the authors commenting on the subject have made little distinction in the use of the terms production, productivity and standing crop. Davis (1963) reviewed the terms and presented suggestions as to their use.

Lac La Biche and Beaver Lake are interesting lakes with respect to standing crop and primary production. The two lakes have a nearly equal standing crop of seston (Fig. 30), which one might expect from a consideration of mean depths. Kerekes (1964) equated the standing crop of seston to productivity. However, he did not take into consideration the rate of turnover or what part of the seston is actively engaged in primary production and what part is merely in a process of decay. Although Lac La Biche and Beaver Lake showed evidence of similar standing crops of seston, from the limited

amount of primary production work done during 1966, there is an indication that Lac La Biche has a photosynthetic activity of about 2.6 times that of Beaver Lake. If this is the case, one is led to the conclusion that Lac La Biche has a turnover rate of autochthonous sestonic material about 2.6 times as fast as that of Beaver Lake. Following this line of reasoning further, if the number of zooplankters per unit volume in the lakes is approximately equal then one would expect that more sestonic material of phytoplanktic origin would settle to the bottom of Lac La Biche than to the bottom of Beaver Lake, possibly resulting in a larger standing crop of bottom fauna in Lac La Biche than in Beaver Lake. From a perusal of Figures 23 and 25, one finds this to be the case. There was 5.6 times as much bottom fauna in Lac La Biche as in Beaver Lake during the two ice-free seasons that bottom samples were collected.

If one was to carry the above line of reasoning one step further, to a consideration of the secondary consumer, one might expect that the fish feeding on this bottom fauna in Lac La Biche would grow as fast as, or faster than, those in Beaver Lake, or there would be many more bottom feeding fish per unit volume in Lac La Biche. If one takes the whitefish, a profundal bottom feeder, or the yellow perch, partially a littoral bottom feeder, into consideration, one finds that in fact the reverse is true. Both whitefish and yellow perch grow faster in Beaver Lake than they do in Lac La Biche. This problem may be at least partially accounted for by the paucity of species that compete for benthos in Beaver Lake as compared to those competing for the same food in Lac

La Biche. Lac La Biche has a large population of two species of suckers while in Beaver Lake one species is found only rarely and the other not at all. Hayes and Anthony (1964) found that, in general, hard waters produce good crops of fish. The waters of Beaver Lake are harder than those of Lac La Biche (Fig. 16).

The rate of primary production can be influenced by the piscine fauna of a lake, according to the size efficiency hypothesis of Brooks and Dodson (1965). They had the opportunity to study the zooplankton of a lake before and after the introduction of the planktonivorous alewife, Alosa pseudoharengus (Wilson), and found that this efficient planktonivorous filter effectively reduced the size of zooplankters inhabiting the lake. Where large forms such as Mesocyclops edax, Diaptomus minutus and large Daphnia sp. were present previous to alewife introduction, Bosmina longirostris and the small Tropocyclops prasinus were the abundant forms after the establishment of a population of these fishes. Brooks and Dodson postulate that the smaller zooplankters cannot feed on the larger algae and do not feed on any algae as efficiently as do the larger zooplankters. This would presumably result in more algae in a lake inhabited by a limnetic planktonivore and hence more primary production.

Much the same situation as that studied by Brooks and Dodson is seen in a comparison of Beaver Lake and Lac La Biche. Lac La Biche has a limnetic planktonivore, tullibee, while Beaver Lake does not. Cyclops vernalis is the dominant zooplankter in Beaver Lake throughout the summer and exhibits

a marked population peak in June in Beaver Lake and begins another peak in the fall just when sampling stopped. In Lac La Biche the same species were present but large forms such as Cyclops vernalis and Daphnia retrocurva did not become nearly so abundant as they did in Beaver Lake. The very small form, Chydorus sphaericus exhibited the same pattern in both lakes, a unimodal curve in the fall. However, from the time it was first present in Lac La Biche it rapidly became the dominant form and was much more abundant in Lac La Biche than it was in Beaver Lake. Its dominance would seem to be at the expense of the large zooplankters which are present only in very low numbers at this time. It is thought that the presence of a planktonivore is having this effect upon the zooplankton of Lac La Biche by not allowing the larger forms to increase in abundance. Chydorus sphaericus is small enough to pass through the gills of tullibee and hence is unaffected by the presence of this planktonivore, but can actually increase markedly because there is a great availability of space and food, and there is not a large enough population of the larger, more efficient feeders to have to compete with. This in turn affects numbers and photosynthetic rate of the algae in Lac La Biche.

Many factors studied could have affected the biota of the two lakes; chemical, geological, morphometrical and downstream connections. These have been postulated to account for some of the differences existing between these two bodies of water. Individual discrepancies of the fauna and flora are dealt with in the Results section. The major

differences, that of abundance of bottom fauna, differences in plankton populations and different rates of primary production are thought to be due, at least in part, to another biological factor, the presence of a limnetic planktonivore. The lakes studied were comparable chemically and in many of the major morphometric measurements. They exhibited similar temperature and dissolved oxygen cycles. While they are in separate drainages, the narrow strip of land separating them is not thought to be sufficient to prevent the interchange of nearly all invertebrate and plant biota. The question of their survival in one or both of the lakes depends principally upon the existence of suitable habitat. Although there are differences in the fish fauna, all forms found in either lake are known to be present in both drainages so these discrepancies are assumed to be due to some factor other than lack of accessibility.

VIII. SUMMARY AND CONCLUSIONS

1. The limnology of Lac La Biche and Beaver Lake, two lakes in northeast Alberta, 218 km (136 miles) from Edmonton, was studied from May 1965 to September 1966. Lac La Biche is in the Athabaska drainage and Beaver Lake is in the Churchill drainage. The lakes are separated by only 3 1/4 km (2 1/4 miles).
2. The morphometric characteristics of both lakes were examined. Lac La Biche is much larger (229.9 km² compared to 33.0 km²) than Beaver Lake. The mean depths are nearly the same (Lac La Biche, 7.4 m, Beaver Lake, 6.9 m).
3. Both lakes show a marked thermal stratification during summer and winter. The periods of spring and fall overturn are of long duration.
4. Curves plotted for hydrogen ion concentration, dissolved oxygen and temperature took very similar forms, clearly defining the epilimnion, metalimnion and hypolimnion.
5. The lake waters exhibited much the same chemical composition, a notable exception being the water of Beaver Lake is harder than that of Lac La Biche.
6. Eight species of fishes were found in Beaver Lake and eleven species in Lac La Biche. Those found only in Lac La Biche were: Catostomus catostomus, Leucichthys sp. and Culaea inconstans. There was a large variation in the abundance of fishes. Perca fluviatilis and Coregonus clupeaformis grew faster, in both length and weight, in

Beaver Lake than in Lac La Biche. Esox lucius grew at much the same rate in both lakes. The length to weight ratio of the above three species was similar for both lakes.

7. The littoral bottom fauna was more diverse than the profundal bottom fauna in each lake. This was due largely to the uniformity of the profundal region in both lakes.
8. There was 5.6 times as much bottom fauna per unit area in Lac La Biche as there was in Beaver Lake.
9. The phytoplankton numbers and composition were studied during 1966. There was a seasonal succession of planktonic algae. Bloom species were characterized as spring, summer and fall blooming species.
10. Zooplankters undergo more marked population fluctuations in Beaver Lake than in Lac La Biche with the exception of the very small form, Chydorus sphaericus. This is thought to be the result of the planktonivore Leucichthys sp. effectively filtering many of the larger zooplankters out of the water, which allows for great population increases of Chydorus sphaericus in Lac La Biche.
11. Although the organic seston content of Lac La Biche and Beaver Lake is nearly the same, primary production experiments indicate that Lac La Biche has a much greater rate of primary production than Beaver Lake. This would indicate a faster turnover rate in Lac La Biche. A faster turnover rate would result in a

greater accumulation of detritus. This is postulated to account, at least in part, for the greater density of bottom fauna in Lac La Biche.

12. Species differences between the biota of the two lakes are not due to a lack of connection between the two lakes, but rather are due to the presence or absence of a suitable type of habitat for particular species in each lake.

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Appendix A. Temperatures of Lac La Biche and Beaver Lake during 1965 and 1966. Expressed in Centigrade degrees.

Beaver Lake, Station 1, 1965.

Depth (m)	June 1	June 14	June 24	July 8	July 20	Aug. 7	Aug. 24	Sept. 7
0	10.6	14.7	16.0	19.6	20.9	22.6	20.3	15.1
1	-	-	15.9	19.6	20.5	22.4	20.3	15.0
2	-	-	15.7	19.6	19.9	22.4	20.3	15.0
3	-	-	15.5	18.7	19.6	22.3	20.3	15.0
4	-	-	15.3	18.5	19.5	22.3	20.3	14.9
5	10.6	14.2	15.3	18.1	19.5	22.1	20.3	14.9
6	-	-	-	17.4	19.4	21.8	20.3	14.9
7	-	-	-	17.2	19.3	21.2	20.2	14.8
8	-	-	15.1	16.2	17.2	20.4	20.2	14.8
9	10.3	13.6	14.6	15.6	16.1	18.2	20.2	14.7
10	9.1	12.5	13.7	14.8	15.2	16.7	19.9	14.7

Beaver Lake, Station 4, 1965.

Depth (m)	June 1	June 14	June 24	July 14	July 23	Aug. 8	Aug. 24	Sept. 7
0	10.5	15.7	16.1	20.3	20.1	25.7	20.2	14.8
1	-	15.6	15.9	20.1	20.1	23.4	20.2	14.8
2	-	14.7	15.8	19.8	20.1	22.9	20.2	14.8
3	-	14.2	15.3	19.5	20.1	21.9	20.2	14.8
4	-	14.2	15.1	19.5	20.0	21.4	20.2	14.6
5	-	14.1	14.8	19.0	19.9	20.7	20.2	14.4
6	10.5	14.1	-	17.1	19.7	20.2	20.2	14.4
7	10.5	14.1	-	15.9	19.5	19.4	20.1	14.4
8	10.5	14.1	-	15.5	18.0	17.7	19.8	14.4
9	10.5	14.0	14.6	15.3	15.5	15.9	19.6	14.4
10	10.4	13.9	14.4	14.6	14.6	15.0	17.9	14.5

Beaver Lake, Station 1, 1966.

Depth (m)	May 20	June 9	June 14	July 7	July 27	Aug. 11	Aug. 22	Sept. 5
0	5.7	9.5	9.3	16.4	22.0	15.5	17.5	12.9
1	5.7	9.4	9.2	16.3	21.3	15.4	17.4	12.8
2	5.7	9.4	9.2	16.2	21.1	16.4	17.3	12.8
3	5.7	9.4	9.1	16.2	21.0	16.3	17.1	12.8
4	5.7	9.3	8.9	16.2	21.0	16.3	17.1	12.8
5	5.7	9.3	8.5	16.1	21.0	16.3	17.0	12.7
6	5.7	9.2	7.8	16.1	21.0	16.3	17.0	12.7
7	5.7	9.2	7.2	16.1	20.9	16.3	17.0	12.7
8	5.7	9.1	6.9	16.1	20.9	16.3	16.9	12.7
9	5.7	8.9	6.8	15.8	20.9	16.3	16.8	12.7
10	5.7	8.7	6.8	13.2	18.7	16.3	16.3	12.7

Beaver Lake, Station 4, 1966.

Depth (m)	May 23	June 14	July 4	July 27	Aug. 4	Aug. 15	Aug. 22	Sept. 5
0	6.3	11.1	17.3	19.2	23.2	21.0	17.3	13.1
1	6.3	11.0	16.5	18.2	20.9	20.9	17.1	12.9
2	6.3	11.0	16.3	18.0	20.3	20.9	17.0	12.9
3	6.3	10.9	16.2	18.0	19.6	20.9	16.9	12.9
4	6.3	10.9	16.1	18.0	19.5	20.8	16.9	12.8
5	6.3	10.9	16.1	18.0	19.3	20.7	16.9	12.7
6	6.3	10.8	16.1	18.0	18.8	20.7	16.9	12.6
7	6.3	10.6	16.1	18.0	18.7	20.7	16.8	12.6
8	6.3	10.5	14.2	17.9	18.4	20.6	16.8	12.4
9	6.3	10.5	11.6	16.6	18.0	20.5	16.7	12.3
10	6.3	10.5	11.1	13.4	17.7	18.7	16.7	12.3

Lac La Biche, Station 1, 1965.

Depth (m)	June 4	June 28	July 6	July 26	Aug. 20	Sept. 9
0	12.2	15.3	19.1	19.7	19.9	13.0
1	11.8	15.2	19.0	19.7	19.9	13.1
2	11.4	15.2	19.0	19.7	19.9	13.1
3	11.3	15.2	19.0	19.6	19.9	13.1
4	11.2	15.1	18.9	19.5	19.9	13.1
5	10.5	14.9	18.8	19.5	19.9	13.1
6	-	14.8	18.8	19.5	19.9	13.1
7	-	14.7	18.8	19.4	19.9	13.1
8	10.1	14.5	18.6	19.1	19.5	13.0

Lac La Biche, Station 3, 1965.

Depth (m)	June 20	July 20	July 28	Aug. 18	Sept. 2
0	15.3	19.8	20.7	20.8	15.7
1	15.3	19.6	20.5	19.7	15.7
2	14.8	19.3	19.8	19.6	15.7
3	14.3	19.1	19.6	19.6	15.7
4	14.2	19.0	19.6	19.6	15.7
5	14.1	19.0	19.5	19.6	15.7
6	-	19.0	19.5	19.5	15.7
7	-	19.0	19.5	19.5	15.7
8	-	18.9	19.4	19.5	15.7
9	-	18.4	19.3	19.5	15.7
10	14.1	18.3	19.2	19.5	15.7
11	-	17.8	18.6	19.5	15.7
12	-	17.7	18.1	19.5	15.7
13	-	17.5	17.9	19.5	15.7
14	-	16.8	17.7	19.5	15.7
15	13.9	16.1	17.6	19.5	15.7
16	-	14.9	16.7	18.3	15.7
17	-	13.7	15.7	16.2	15.7
18	-	13.5	14.4	15.2	15.7
19	-	13.3	14.0	15.2	15.7
20	-	13.1	13.8	14.8	15.6

Lac La Biche, Station 1, 1966.

Depth (m)	May 26	June 9	June 24	July 4	July 22	Aug. 4	Aug. 22	Sept. 5
0	8.3	9.2	13.7	16.7	19.5	20.9	16.7	13.1
1	8.1	9.2	13.5	16.7	19.6	20.4	16.6	12.9
2	7.9	9.1	13.3	16.6	19.6	19.7	16.6	12.8
3	7.8	9.1	13.1	16.6	19.6	19.5	16.5	12.5
4	7.6	9.1	13.1	16.5	19.6	19.4	16.5	12.3
5	7.5	9.0	12.9	16.4	19.6	19.1	16.4	12.3
6	7.0	8.9	12.9	16.3	19.5	18.8	16.3	12.3
7	6.6	8.9	12.8	16.2	19.4	18.3	16.2	12.3
8	6.4	8.9	12.7	16.0	19.4	18.2	16.2	12.3

Lac La Biche, Station 3, 1966

Depth (m)	May 26	June 16	July 4	July 27	Aug. 4	Aug. 11	Aug. 22	Sept. 5
0	7.7	11.6	16.1	23.1	24.8	18.6	16.8	14.0
1	7.4	10.9	16.1	22.2	23.4	18.6	16.8	13.4
2	7.3	10.6	15.9	20.6	22.7	18.6	16.8	12.8
3	7.0	10.5	15.8	20.5	22.5	18.6	16.7	12.7
4	6.2	10.5	15.7	20.4	22.5	18.5	16.6	12.7
5	6.2	10.5	15.7	20.3	22.4	18.5	16.6	12.7
6	5.8	10.5	15.5	20.3	22.0	18.5	16.5	12.5
7	5.6	8.5	15.4	20.3	21.7	18.5	16.5	12.4
8	5.5	8.5	15.4	20.3	21.5	18.5	16.5	12.2
9	5.5	8.1	15.4	20.3	21.5	18.5	16.4	12.2
10	5.4	7.8	15.4	20.3	21.2	18.5	16.4	12.2
11	5.4	7.7	15.3	20.3	21.1	18.5	16.4	12.2
12	5.4	7.5	15.3	20.3	20.9	18.5	16.4	12.2
13	5.4	7.4	15.3	20.3	20.9	18.5	16.4	12.2
14	5.4	7.3	15.3	20.3	20.8	18.5	16.4	12.2
15	5.3	7.3	15.3	20.2	20.6	18.4	16.4	12.2
16	5.3	7.2	11.6	20.2	20.4	18.4	16.4	12.2
17	5.3	7.2	10.9	20.2	19.3	18.4	16.3	12.2
18	5.3	7.2	10.4	20.1	18.7	18.4	16.2	12.2
19	5.3	7.1	10.3	17.5	18.8	18.4	15.7	12.1
20	5.3	7.0	8.1	15.5	-	18.0	15.5	12.1

Appendix B. Dissolved Oxygen and Hydrogen Ion Concentration of Waters of Lac La Biche and Beaver Lake During 1965 and 1966.

Beaver Lake

Date	Station	Depth (m)	Dissolved Oxygen, ppm	pH
24/6/65	1	0	9.5	7.9
"	1	9	7.1	7.9
"	2	0	9.3	7.9
"	2	10	8.7	7.9
"	3	0	9.6	7.8
"	3	9	8.1	7.8
"	4	0	9.6	7.6
"	4	9	8.1	7.6
14/7/65	1	0	9.3	8.1
"	1	5	8.5	-
"	1	6	8.3	-
"	1	7	4.1	8.1
"	1	8	4.1	7.6
"	4	0	10.0	-
"	4	5	9.3	-
"	4	6	9.9	-
"	4	7	4.4	-
8/8/65	1	0	10.0	8.9
"	1	5	10.0	8.9
"	1	6	10.1	8.9
"	1	7	8.1	8.9
"	1	8	1.9	7.6
"	1	9	1.3	7.6
"	4	0	16.2	8.9
"	4	5	5.7	-
"	4	7	3.3	-
"	4	8	2.3	7.8
26/8/65	1	0	7.6	8.8
"	1	9	7.6	8.8
7/9/65	1	0	8.3	8.8
"	1	9	7.6	8.5
"	3	0	8.3	8.6
"	3	9	7.1	-
"	4	0	7.2	8.6
"	4	10	6.9	8.6
23/5/66	1	0	9.9	8.6
"	1	10	9.9	8.6
"	4	0	10.3	8.6
"	4	10	10.0	8.6
14/6/66	1	0	10.6	8.4
"	1	10	6.2	8.2
"	4	0	11.6	8.8
"	4	10	10.2	8.8
4/7/66	1	0	8.4	-
"	1	10	7.8	-
"	4	0	9.4	-
"	4	10	1.0	-
15/8/66	1	0	8.2	8.6
"	1	10	7.5	8.6
"	4	0	7.2	8.4
"	4	10	6.6	8.6
5/9/66	1	0	8.2	8.8
"	1	10	8.2	8.6
"	4	0	9.6	8.6
"	4	10	9.2	8.8

Lac La Biche

Date	Station	Depth (m)	Dissolved Oxygen, ppm	pH
28/6/65	1	0	9.3	7.4
"	1	8	8.3	7.4
"	2	0	10.6	-
"	2	10	9.0	-
"	3	0	10.6	7.4
"	3	19	8.0	7.6
26/7/65	1	0	8.9	8.2
"	1	8	8.9	-
"	2	0	9.2	8.2
"	2	9	8.3	8.4
"	3	0	8.9	8.3
"	3	7	8.0	8.2
"	3	10	7.4	8.3
"	3	14	5.6	7.7
"	3	17	2.3	7.2
18/8/65	1	0	5.9	8.8
"	1	8	5.7	8.8
"	2	0	5.2	8.8
"	3	0	8.6	8.3
"	3	16	6.4	8.3
"	3	17	1.9	7.5
"	3	19	1.0	7.5
10/9/65	1	0	8.9	7.9
"	1	8	8.7	7.9
"	2	0	8.9	7.9
"	2	9	8.6	7.9
26/5/65	1	0	10.3	8.4
"	3	0	11.3	8.6
"	3	18	10.0	7.6
16/6/66	1	0	9.6	8.2
"	1	9	8.4	8.4
"	3	0	9.6	8.1
"	3	5	9.6	8.0
"	3	10	9.0	8.0
"	3	16	8.0	8.0
4/7/66	1	0	10.0	-
"	1	9	5.0	-
"	3	0	10.0	-
"	3	10	3.6	-
"	3	15	3.2	-
"	3	17	1.6	-
"	3	19	1.8	-
15/8/66	1	0	9.0	8.8
"	1	9	8.5	8.6
"	3	0	8.4	8.6
"	3	16	5.9	8.6
"	3	19	5.9	-
5/9/66	1	0	10.4	8.8
"	1	9	9.4	8.8
"	3	0	10.6	8.8
"	3	19	8.8	8.8

Appendix C. Commercial Catch of Fishes from Lac La Biche
and Beaver Lake from 1942 to 1966. Values
Expressed in Pounds*.

* Data from files of Fish and Wildlife
Division, Government of Alberta.

Lac La Biche

Year	Lic.	Mixed	Tullibee	Perch	Walleye	Pike	Whitefish	Total	lb/lic.
42/43	102		1,087,142	400	10,026	36,089	122,713	1,256,370	12,563
43/44	118	6,588	1,136,484		49,650	97,191	77,501	1,376,414	11,665
44/45	128		1,550,600	17,213	102,717	41,476	9,736	1,721,742	13,451
45/46	157	300	1,549,302	49,751	84,094	41,870	1,804	1,727,121	11,000
46/47	245	298	2,669,601	116,508	129,032	100,814	537	3,016,790	12,313
47/48	151	57,582	22,988	98,576	5,523	53,736	4,534	242,939	1,609
48/49									
49/50	78	139,677	19,296	1,823	3,771	186,309		350,876	4,498
50/51	101	130,466	278,140	1,060	7,210	66,914	9,684	493,474	4,935
51/52	184	40,420	531,295	300	81,044	172,247	75,552	900,858	4,896
52/53	194	10,878	190,159	545	39,108	36,215	123,745	400,650	2,065
53/54	211	157,966	133,783	1,163	2,708	90,276	108,938	494,834	2,345
54/55	111	139,800	16,350	4,495		75,550	2,485	238,680	2,150
55/56	233	145,154	201,500	815	6,952	64,866	59,025	478,312	2,053
56/57	314	350,604	657,222	5,340	16,387	8,721	110,931	1,149,205	3,660
57/58	339	518,906	728,450	8,596	24,475	15,258	285,758	1,581,443	4,665
58/59	699	540,920	1,069,986	3,869	25,752	23,771	529,329	2,193,627	3,138
59/60	762	139,987	1,030,150	5,516	17,599	41,019	579,394	1,813,665	2,380
60/61	784	61,121	1,913,818	7,817	15,770	126,461	778,946	2,903,933	3,703
61/62	419	54,193	398,362	2,858	13,420	146,427	189,145	804,405	1,920
62/63	295	18,354	316,958	9,285	15,673	62,765	68,824	491,859	1,667
63/64	345	67,561	1,091,252	12,394	4,005	17,233	71,594	1,264,039	3,663
64/65	413	147,660	2,568,402	295,838	2,245	20,755	215,378	3,250,278	7,870
65/66	413	59,503	781,090	617,436	5,391	18,701	197,746	1,679,867	4,067

Beaver Lake

Year	Lic.	Mixed	Tullibee	Perch	Walleye	Pike	Whitefish	Total	lb/lic.
42/43	18			2,219	15,710	27,699	30,514	76,142	4,230
43/44	54			9,839	19,296	55,466	117,856	202,457	3,749
44/45	48			9,525	5,280	23,117	60,759	98,681	2,055
45/46	125			10,633	8,217	13,893	89,956	122,699	981
46/47	67	177		37,043	20,483	9,652	35,291	102,646	1,532
47/48	60	433		45,791	38,530	33,223	15,351	133,763	2,229
48/49	45			16,349	6,465	26,088	31,802	80,704	1,793
49/50	17			340	1,995	3,113	16,061	21,509	796
50/51	13				1,237	474	16,682	18,563	1,428
51/52	24			3,737	4,147	18,776	2,406	29,066	1,211
52/53	63			4,758	2,817	25,503	27,006	60,084	953
53/54	82	183		3,603	1,275	28,663	53,006	86,790	1,058
54/55	136			1,683	26,679	1,346	34,051	63,759	469
55/56	41			1,137	275		4,628	6,060	147
56/57	60	4,518		534	682	7,162	13,077	25,973	432
57/58	18			47	832	2,244	1,186	4,309	239
58/59	119	2,276			540	1,960	14,257	16,533	138
59/60	128	4,341			526	1,182	39,252	46,093	360
60/61	168	3,592		50			24,887	30,237	180
61/62	232	2,224		160	335	2,847	48,859	54,425	235
62/63	234	1,500			100	1,000	61,400	64,000	274
63/64	260	5,163			457	600	45,747	51,967	200
64/65	216	8,500			187	500	46,680	55,867	214
65/66	232	6,600		800	741	13,464	53,252	74,857	322

Appendix D. Numbers of Zooplankters in Beaver Lake and
Lac La Biche During 1966.

Lac La Biche

Number per litre

Station	Date	<u>Chydorus</u>	<u>Daphnia</u> <u>retrocurva</u>	<u>Daphnia</u>	<u>Diaphanosoma</u>	<u>Bosmina</u>	<u>Cyclops</u>	<u>Diaptomus</u>
1	25/5/66	0	1	0	0	0	63	46
2	"	0	0	0	0	0	45	45
3	"	3	0	0	0	0	55	65
1	9/6/66	0	3	0	0	2	62	34
1	16/6/66	2	8	0	0	0	193	42
3	"	2	6	0	0	0	92	89
1	4/7/66	3	22	0	0	0	22	7
2	"	0	55	0	0	0	42	157
3	"	6	67	0	0	0	72	70
1	22/7/66	14	3	0	0	0	7	11
3	"	27	17	4	0	0	42	62
1	12/8/66	25	0	0	4	0	3	26
3	"	14	1	0	1	0	9	1
1	29/8/66	29	5	0	3	3	3	5
3	"	261	8	0	9	0	34	14
1	5/9/66	76	8	0	4	0	14	3
3	"	353	11	0	7	2	53	12

Beaver Lake

		Number per litre						
Station	Date	<u>Chydorus</u>	<u>Daphnia retrocurva</u>	<u>Daphnia</u>	<u>Diaphanosoma</u>	<u>Bosmina</u>	<u>Cyclops</u>	<u>Diaptomus</u>
1	25/5/66	27	0	0	0	0	49	4
2	"	3	0	0	0	0	85	17
3	"	13	0	2	0	0	78	8
4	"	10	2	2	0	0	108	5
1	9/6/66	21	7	0	0	0	218	7
1	14/6/66	10	3	2	0	2	214	22
2	"	34	11	2	0	4	320	27
3	"	24	7	2	0	3	238	18
4	"	25	17	0	0	2	300	24
1	24/6/66	70	56	6	0	22	482	65
1	4/7/66	117	229	0	0	6	336	11
2	"	104	50	6	0	3	190	25
3	"	55	59	9	0	9	300	6
4	"	43	66	10	0	2	162	24
1	22/7/66	13	24	2	0	0	58	13
4	"	8	27	3	0	0	34	8
1	11/8/66	109	41	0	18	0	76	45
4	"	36	39	0	7	0	28	11
1	29/8/66	130	10	0	3	6	73	70
4	"	63	20	0	1	9	38	46
1	5/9/66	206	17	0	4	2	191	34
4	"	94	43	0	2	6	146	50

Appendix E. Total Dry Weight, Organic Content and Per Cent Organic Content of Two Liter Seston Samples From Lac La Biche and Beaver Lake During 1965.

Lac La Biche

Station	Depth (m)	Date	Total Dry Wt. (mg)	Organic Content (mg)	% Organic
1	0	28/6/65	12.6	5.6	44
2	0	29/6/65	5.1	3.6	71
2	5	"	12.0	3.6	30
3	0	"	8.2	4.6	56
3	5	"	9.2	5.4	59
3	20	"	12.7	5.3	42
1	0	26/7/65	6.7	4.3	64
1	6	"	7.8	4.9	63
2	0	"	9.4	7.4	79
2	8	"	8.5	5.8	68
3	0	"	8.7	5.2	60
3	8	"	6.8	4.8	71
1	0	20/8/65	8.7	7.5	86
1	6	"	5.9	4.9	83
2	0	"	8.6	7.0	81
3	0	"	10.3	7.0	68
1	0	10/9/65	7.6	4.6	61
1	6	"	5.6	4.5	80
2	0	"	11.7	5.2	44
1	0	13/11/65	5.0	2.5	50
3	0	29/12/65	3.9	2.7	69
3	5	"	5.4	5.0	93

Beaver Lake

Station	Depth (m)	Date	Total Dry Wt. (mg)	Organic Content (mg)	% Organic
1	0	24/6/65	7.7	3.7	49
1	5	"	7.4	2.7	39
2	0	"	5.9	4.3	73
3	0	"	7.4	2.7	36
4	5	"	6.5	3.7	57
1	0	22/7/65	5.0	4.1	82
1	1	"	13.6	4.8	35
2	0	"	6.8	4.9	72
3	8	23/7/65	4.4	3.3	75
4	0	"	5.4	4.0	74
4	8	"	6.1	5.4	89
1	0	12/8/65	6.3	6.1	97
2	0	"	6.5	5.9	97
3	0	"	6.6	6.5	98
4	8	"	4.8	4.7	98
1	0	9/9/65	7.5	4.6	61
1	8	"	7.8	5.6	72
3	0	"	10.0	7.1	71
4	0	"	38.6	14.6	38
4	8	"	8.0	5.4	68
1	0	13/11/65	12.5	6.0	48
1	5	"	8.4	4.0	48
1	0	28/12/65	16.1	4.6	29
1	5	"	31.7	6.9	28
3	0	"	33.2	5.2	16

Appendix F. Dissolved Oxygen Values Obtained From Light
Bottle-Dark Bottle Experiments and the Method
Used for Conversion to Milligrams of Carbon
Assimilated.

Table F₁. Amount of Dissolved Oxygen, in ppm, in Dark and Light Bottles After Ten Hours Suspension in Beaver Lake and Lac La Biche During 1966.

		Light Bottle	Dark Bottle	LB-DB
June 30	Lac La Biche	9.10	7.50	1.60
	Beaver Lake	9.30	8.80	0.50
July 29	Lac La Biche	9.85	8.40	1.45
	Beaver Lake	8.40	7.80	0.60
August 12	Lac La Biche	9.80	7.40	2.40
	Beaver Lake	8.40	7.40	1.00

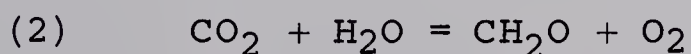
Method of Conversion of Dissolved Oxygen from Light Bottle- Dark Bottle to Carbon Assimilated.

An estimate of the amount of primary production taking place in lake waters was done using the difference in dissolved oxygen in a light bottle and that in a dark bottle. This amount of oxygen was then converted to the amount of Carbon assimilated by the phytoplankton. This conversion was carried out in the following manner:

The amount of dissolved oxygen (LB-DB) was expressed in parts per million, or milligrams per litre. This value was then converted to milligrams of Carbon per litre by the formula:

$$(1) \quad X = \frac{\frac{\text{mgm/l O}_2 \times 12}{32}}{1.25}$$

The above formula was derived from a consideration of the simplified formula for a photosynthetic reaction:



It has been shown (Ryther, 1956) that the oxygen evolved from this process originated from the carbon dioxide on the left hand side of the formula, and hence can be considered equal on both sides of the equation. It remains then, only to determine the amount of carbon combining with this amount of oxygen to attain the amount of carbon assimilated into carbohydrate by the photosynthetic process. This is done by comparing them thus:

$$(3) \quad \frac{C}{12 = (\text{mol. wt. of C})} = \frac{\text{O}_2}{32 = (\text{mol. wt. of O}_2)}$$

This is easily converted into formula (1) with the exception of the value 1.25. This value is suggested by Ryther (1956) as a photosynthetic quotient for use in determinations of this kind.

Appendix G. Numbers and Year of Life of Fishes Used
in Determination of Growth Curves.
(Raw data available at Department of
Zoology, University of Alberta)

Species	Year of Life	Number in Sample	
		Beaver Lake	Lac La Biche
<u>Coregonus</u>			
<u>clupeaformis</u>	1	0	0
	2	16	0
	3	3	10
	4	13	2
	5	14	4
	6	15	7
	7	5	2
	8	0	2
<u>Perca</u>			
<u>fluviatilis</u>	1	17	2
	2	5	1
	3	25	4
	4	9	8
	5	4	25
	6	5	14
	7	1	3
<u>Esox lucius</u>			
	1	3	3
	2	3	1
	3	9	4
	4	48	5
	5	47	8
	6	13	7
	7	6	4
	8	1	1
<u>Stizostedion</u>			
<u>vitreum</u>	1	0	-
	2	5	-
	3	18	-
	4	18	-
	5	5	-
	6	4	-
<u>Leucichthys</u> sp.			
	1	-	0
	2	-	1
	3	-	13
	4	-	19
	5	-	18
	6	-	5
	7	-	3
	8	-	1
<u>Catostomus</u>			
<u>commersoni</u>	1	-	2
	2	-	5
	3	-	6
	4	-	18
	5	-	19
	6	-	1
	7	-	3

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